TELESCOPE MAKING 35

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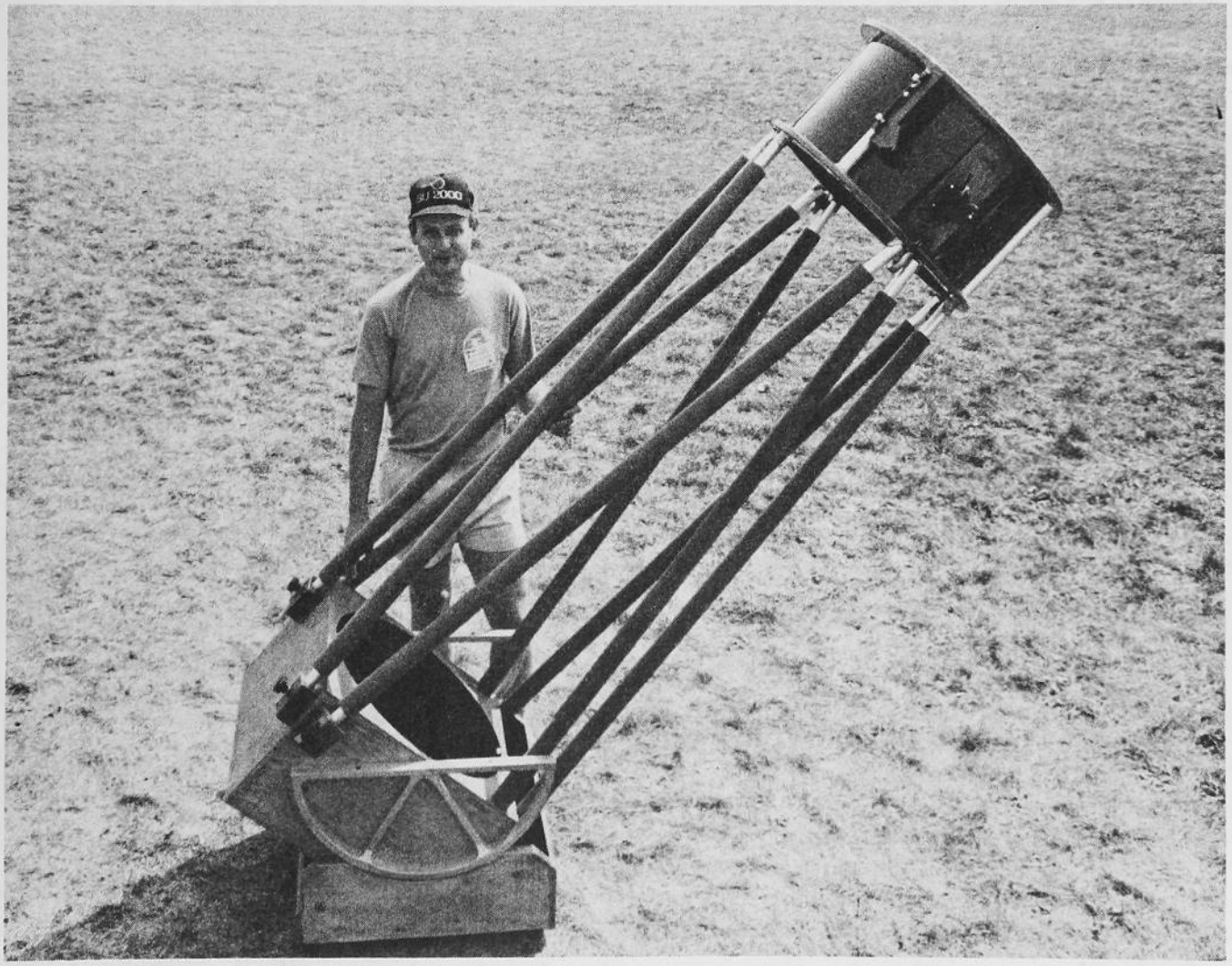

Dobsonian Evolution

Telescope Making #35

The magazine *for*, *by*, and *about* telescope makers!

Editor: Richard Berry
Associate Editor: Robert E. Cox
Managing Editor: Stephen Cole

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Cover: Dave Kriege's "evolved" 20-inch f/5 Dobsonian, *Obsession 1*. Photo taken at Astrofest by Richard Berry.

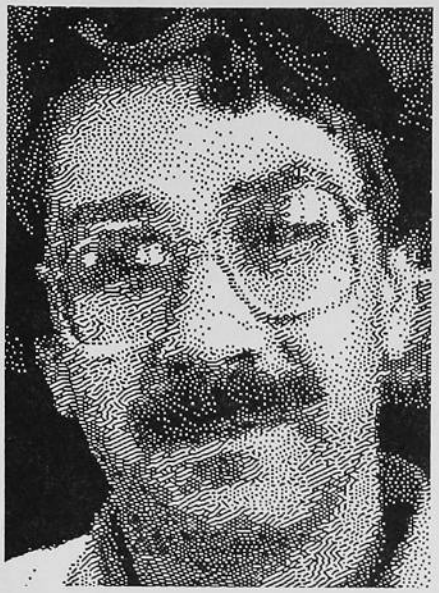
Editorial

Three years ago, I thought the Dobsonian revolution had gone about as far as it was going to go. Innovative telescope makers were thinking about other things, and Dob builders seemed to be dotting the i's and crossing the t's. The design looked mature, and that was that. *Finis.*

Boy, I was wrong.

The Dobsonian has continued to evolve. Dave Kriege's 20-inch is the easiest and "funnest" big telescope I've ever used. It moves so smoothly and with such a light touch that observing Mars at 300x is no problem at all. Ron Ravneberg's many refinements add up to a functionality and convenience no Dobsonian built three years ago can match. And Pete Smitka beat down the hassles of transport, tracking, and dewing, to show that the goal of the whole telescope game is to put the eye to the eyepiece—and that every link in the chain must be optimized for the "observing system" to function. Finally, with a supply of large, low-price, high-quality mirrors coming onto the market, we're seeing that Dobsonians are capable of top-notch performance at full aperture.

In assembling this issue of *Telescope Making*, we're presenting a challenge to every telescope maker: can you top this? Kriege began with some basic research that nobody else bothered with in five years—he tested friction in materials—and



achieved a breakthrough in bearing size and smoothness. Ravneberg forced the pole problem toward its logical conclusion, by using identical tubes clamped in place. And Smitka has reminded us that the telescope is only part of the system.

In each case, somebody put a different spin on the ball, and came up with new answers to old problems, just as Dobson did when he realized that the alt-azimuth had vast unexplored potential. Seeing such advances occur is what makes telescope making so much fun.

Meanwhile, back in the optics shop things are cooking, too. I believe that the big Schiefspieglers are an indicator, and the current interest in them shows there's a demand out there for high-definition optical systems. Like it or not, there aren't going to be a lot of 10-inch apochromatic refractors built because the glass is far too expensive. Harrie Rutten and Martin van Venrooij (pronounced "ven-ROY") have designed a better-than-refractor quality catadioptric with a spherical primary, a small obstruction ratio, and cheap glasses. They'll report on the prototype and its performance in an upcoming issue of *TM*. I'm expecting to see an apochromatic Rutten telescope one of these days.

The next issue, *Telescope Making #36*, will go to the printer on March 21, give or take a couple days. See you then.

Sincerely,

Richard Berry
Editor

Letters

Seeking Good Optics

Dear Mr. Berry,

As a new subscriber, I have already gotten my money's worth from my first two issues, *TM#32* and *TM#33*. I put the articles by Dick Suiter and Robert Follett to immediate use as valuable adjuncts to my copy of Texereau.

Over two years ago I ordered a thin 16-inch mirror from an optics company (one of your advertisers) who specifies their optics to be of 20th-wave quality. Many months after the initially stated delivery time the mirror finally arrived. This was okay because the mechanics were not ready, and besides, I thought, perfection can't be hurried. I put the mirror away for a few months and continued to work on the mechanics, but some nagging doubt caused me to ask an optician friend of mine to test the mirror for me.

I made a mask and we did a zonal test on the mirror. To my great distress, the mirror figure was in error by 3/4 wave! I sent the mirror back, and a few months later, I got the replacement. This time, I not only had the zonal test done, but I also had it tested by a Zygo Mark IV interferometer, which confirmed that the replacement mirror was also unusable. The second mirror had bad astigmatism! I never imagined that there would be any nonaxisymmetric errors. The Zygo analysis showed, interestingly enough, that without the astigmatism, it would have been a pretty good mirror.

I asked for and received a prompt refund. I then ordered a 14.5-inch lightweight mirror from Telescopics—at twice the price. I have done a zonal test on this mirror and used Dick Suiter's version of the M-L method to evaluate the results, and it looks as though I finally have good mirror. Whew!

At the same time we Zygo tested my second 16-inch mirror, we tested a 10-inch mirror from the well-known maker of large Dobsonians. It turned out to also have the very bad astigmatism along with other errors. This mirror was sent back to the vendor and after four and a half months of excuses ("We're having trouble with our pitch laps") another 10-inch mirror arrived.

Last night we did star tests using the telescope, and the images were terrible, and the owner said the intrafocal and extrafocal star images had the same peculiar notched and flared appearance as the previous mirror had delivered. By judicious use of an off-axis stop, we found that the diagonal mirror had a bad area, and once we got the focused beam on a reasonably flat part of the diagonal mirror, the images were pretty good.

My suspicions about the diagonal mirror had already been aroused because by this time I had interferometer-tested and rejected three diagonal mirrors from two different vendors. I am still waiting to get a good diagonal mirror.

I never imagined that I was going to have to work so hard just to verify the optics vendor's guaranteed specifications. I have concluded from these experiences that there must be a large number of large telescopes out there with expensive shaving mirrors in them, and that these badly aberrated wavefronts are further mutilated by the diagonal mirrors.

I wonder what their owners are telling themselves about those images: "Gosh, if the seeing ever gets good, this big Dob is really going to perform."?

I want to reinforce Dick Suiter's advice: Whether you make or buy plan to get into optical testing seriously, and that includes testing the diagonal. Using Texereau's method of testing the diagonal in conjunction with a spherical mirror, I was unable to get any quantitative measurements of it. I was just barely able to detect shadows on one side of the mirror, which verified the eighth wave surface error shown there by the Zygo.

I would like to see an article about a good method of testing diagonal mirrors that will give quantitative data about the surface. I wonder if using aperture stops to illuminate different parts of the diagonal mirror could be the basis of a way to do this, assuming of course that the primary mirror has already been verified to be good.

John J. Brooks
1337 Highland Road
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-- The obvious answer is to interference test against a flat of known quality—but that requires a good flat, and that's what you don't have. Readers: any good ideas? Please

Continued on page 51...

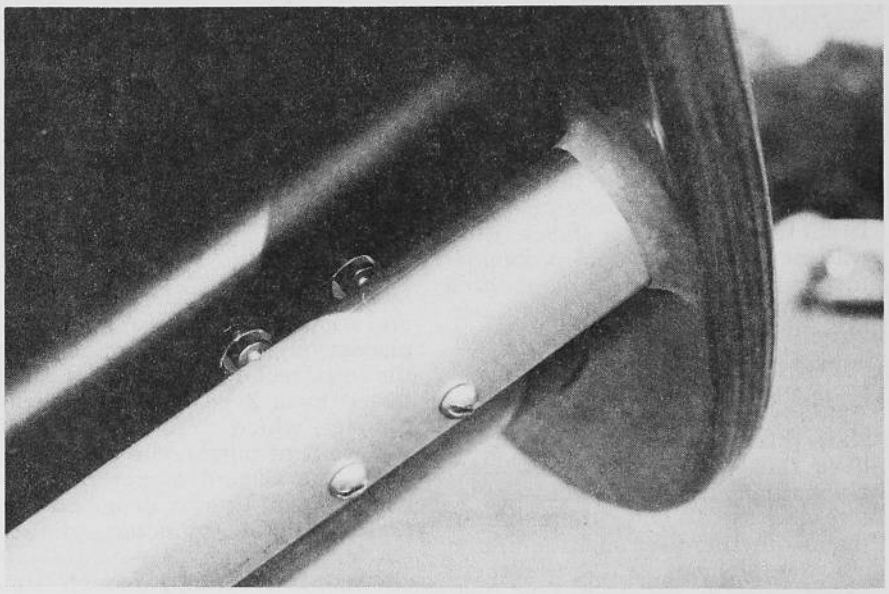
Dobsonian Evolution
—
The Construction of Obsession 1

The Dobsonian design for large-aperture telescopes is fundamentally excellent, as many amateur astronomers know. What I have done is taken Dobson's original concepts and tried to maximize them to their full potential. By researching different construction materials and applying a few innovations borrowed from other TMs, I think I've been able to realize "Obsession 1"– my 20-inch f/5 Dobsonian.

History

To begin, a little development history is in order. I built three small Newtonian reflectors on permanent equatorial mounts twenty years ago when I was a teenager, so I'm familiar with the limitations of traditional designs. To get back into astronomy and telescope making, I decided it would be smart to get some current information, so I went to Astrofest '87. There I met Bill Burton, the regional "Don King" of telescope making. At that time I didn't even know what a Dobsonian was. Bill showed me his scope and told me all about the advantages of a Dob. I was hooked. I went home, ordered every back issue of *Telescope Making*, and immediately set out to make the largest telescope I could afford.

After pushing around memories of problems I've had with my previous telescopes, I soon realized I would have to optimize the design if I was going to satisfy my newly found aperture fever. I wanted to make a really big reflector that was inviting to use. I knew that if my telescope was difficult and time consuming to set up, wasn't portable, wasn't fun to operate, and, last, wasn't optically excellent, I would probably end up watching TV instead of the sky on clear nights.



A light-weight secondary cage is essential if you want a low-profile rocker. Epoxy, thin-wall tube, and 10-mil Mylar plastic keep it light.

Cage

Starting at the top, the cage rings are fabricated from 3/4-inch Baltic Birch plywood. Baltic Birch is 13 ply and extremely strong. It is also expensive and comes in 5-by-5 foot sheets. (Ever try picking up something like that?) Both rings are 1.75 inches wide and are separated by four 1-1/4-inch O.D. 055 anodized aluminum tubes 12 inches long.

To save weight and increase strength, the tubes are attached with the new epoxy putties available at most hardware stores. A 2-inch-long plug of denture acrylic was poured into each tube where the spider vanes attach to prevent flattening. The spider and holder are Novak's with a 3.1-inch secondary offset 1/8-inch "down and away" for optimum focal-plane illumination. For visual astronomy, a 3.1-inch secondary provides less obstruction without significant light loss if the focal plane is kept as close to the diagonal as possible. To do so, a 2-inch low-profile focuser was mounted on a 1/4-inch-thick piece of hobby ply used in making model airplanes. This in turn is mounted on the inside of the rings.

Last, I painted a sheet of 0.010-

David Kriege's advanced Dobsonian telescope was on display at the 1988 Astrofest meeting, held near Kankakee, Illinois last September.

inch Mylar black and wrapped it inside the cage shiny side out. It's held to the rings with 3M double-sided tape used to weather-seal windows. The result is a strong, rigid cage assembly that is very lightweight. Including the secondary and pole fittings, it weighs in at only ten pounds. Minimizing cage weight is half the secret to the ultra-short-profile rocker base described later.

Pole Fittings

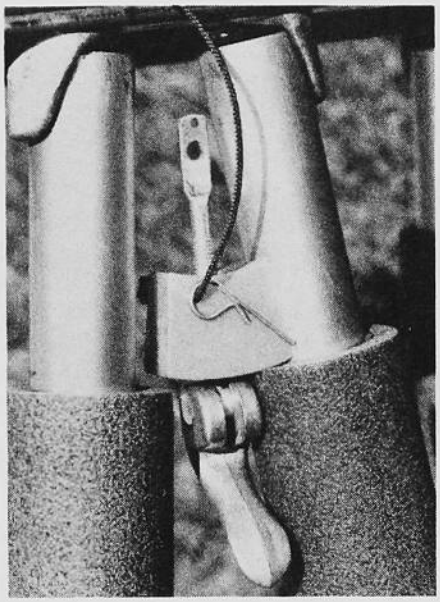
The telescope uses the Serrurier truss to connect the mirror box to the cage. The poles are made from the same tubing described above. I covered them with closed-cell foam pipe insulation (Roger Tanner, *Telescope Making #32*) to dampen vibration and provide a warm grip on cold nights. Thanks to Ron Ravneberg, whom I also met at Astrofest, the poles are attached to the cage using his proven seat and wedge design. I patterned the pole seats out of acrylic and had them cast in aluminum.

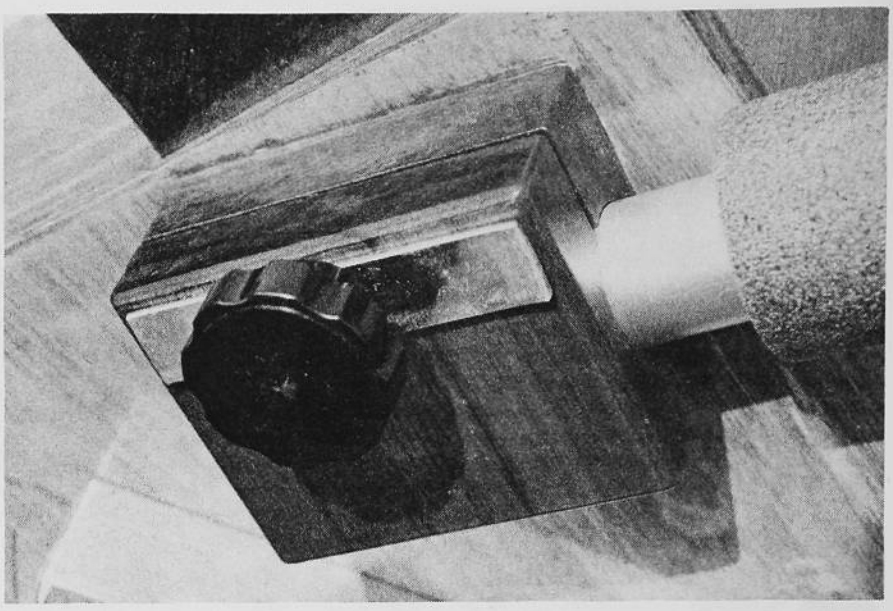
I cast the wedges in denture acrylic through which a hole was drilled to freely accept a "flat ended" bolt. An aluminum quick-release cam lever from my canoe car-top carrier provided the wedging force. Simply pass the bolt-wedge-cam assembly in between the poles, retain the bolt with a nail or fancy hitch pin, and throw the lever. You're done. It's fast, adjustable, requires no tools, and can be done in the dark.

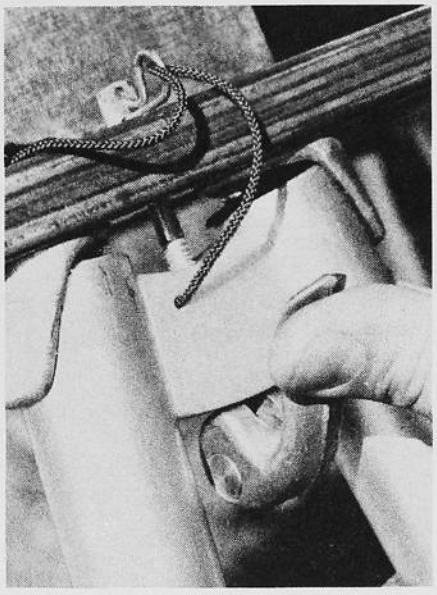
Mirror Box

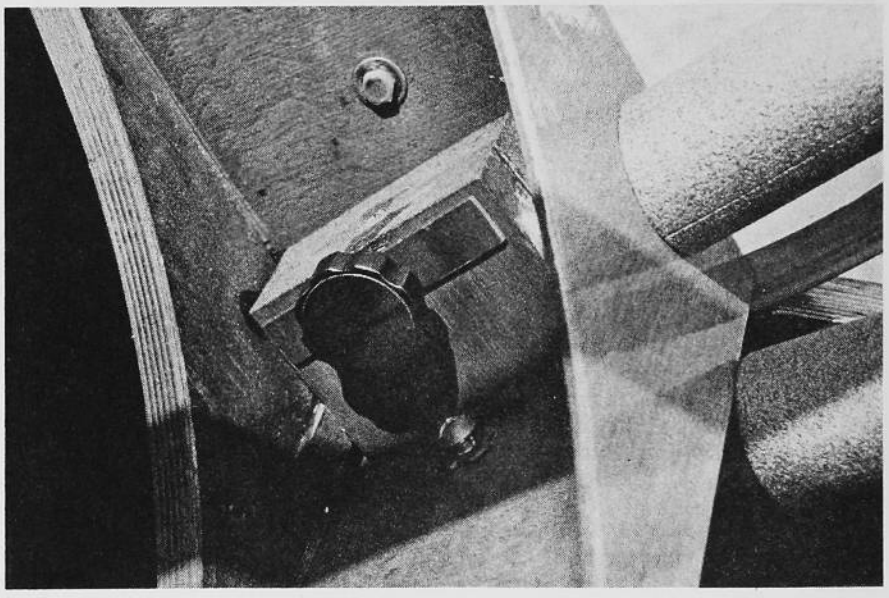
Considerable thought went into the mirror box. I wanted it to be as small and as light as possible; very low profile; a permanent home for the mirror; mate to the truss poles efficiently; and still balance the cage assembly six feet away. If I could achieve my goals, I knew I could make a 100-inch focal length telescope that would present the eyepiece only 7-1/2 feet above the ground at zenith. I must have succeeded because other amateurs upon first glance always assume the instrument is a 16- or 17.5-inch.

The mirror box is 24 inches square inside and only 16 inches deep. The pivot point of the tele-









Quick-release cams and split wood blocks make assembly quick, repeatable, and easy. Note lower poles are placed inside the side bearings.

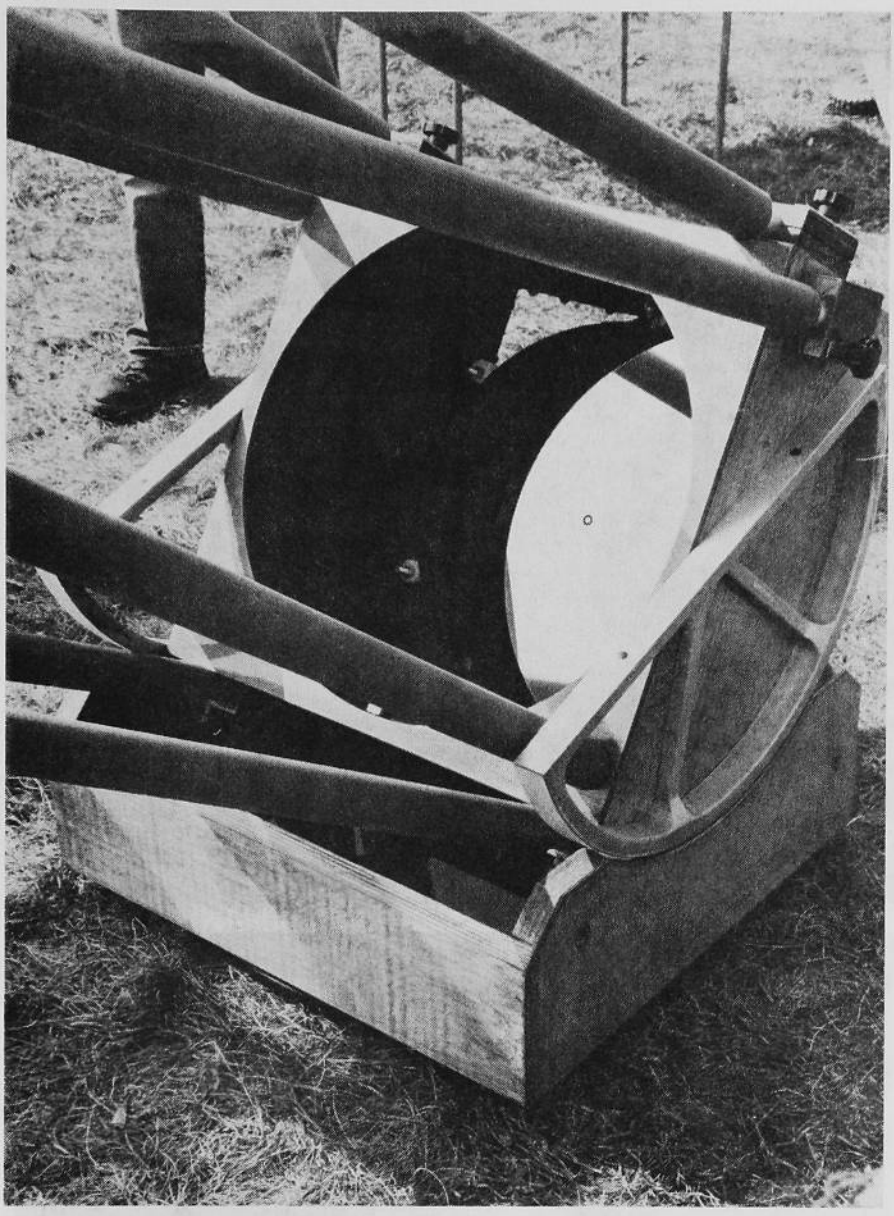
scope is right at the top of the box, thus all of the mass can be used to counter balance the cage. In addition, I cut out the lower corner of the box on one side exposing the mirror. Tilting the telescope in altitude permits the bottom edge of the mirror to just pass 1/4 inch above the bottom of the rocker, further reducing the height of the rocker sides.

With internal corner braces, a light baffle on top, and a welded steel tailgate, the box is stronger than it needs to be. If I had to do it all over again, I would have used 1/2-inch ply instead of the heavier 3/4 inch. All those glue layers really ate up my saw blades!

The poles connect to the box with high grade mahogany split blocks. I chose mahogany for its resistance to splitting. It's not as hard as oak or maple, but it bends easier and it's still harder than pine. I placed six of the blocks outside of the box to allow for easy access, but more importantly, to broaden the base of the truss for strength. The two blocks adjacent to the altitude bearings had to be mounted inside, yet they are in the same position relative to the cage as the others except that the angle is out– not in. Thus all the poles are interchangeable.

To make the split blocks, I started with 3-foot length 2x8 mahogany plank. With a 1.25-inch spade bit, I drilled eight holes into the plank on an angle approximating the out or in angle of the poles. To do this, I fooled the drill press by nailing the plank to a scrap piece of plywood raised on one edge to yield the desired angle. Then I cut out the blocks, cut the splits, and fine adjusted the mating surfaces with a belt sander after rigging everything plumb and squared-up in my garage.

After two days of fitting and positioning, I finally got up the nerve and glued them to the box. Knurled knobs with threaded rods run through the splits and into T-nuts squeezing the poles and holding them nicely. Probably the most difficult part of the entire project to make was the split block and its alignment, but they were worth



doing. Setup is fast and accurate, and the poles don't sway around in the dark when I'm trying to set the cage on top.

Mirror Cell and Tailgate

John Hudek of Galaxy Optics supplied the mirror. Fabricated from a 2-inch-thick modeled Pyrex blank and figured to a focal length of 100 inches, it arrived on my door step *two months* after I ordered it. I talked with John at length before placing my order and he assured me of a quality optic as long as I supported it properly. I was not disappointed.

To me, supporting a large mirror properly means a good flotation cell and no lateral stresses. To accomplish this, the mirror is slung in a 2-inch-wide nylon seat belt from an old Ford. To prevent lateral dislodgement during transport, I borrowed another one of Ron Ravneberg's innovations: off-center pins. Five 1-inch-diameter by 2-inch-long plastic dowel pins were drilled slightly off center. When placed over a bolt, each can be adjusted to center the mirror in the box.

I left a 1/32-inch space between them and the glass when the mirror hangs in the sling. The result is that the mirror is captive when bouncing down the road, yet suffers no lateral stresses in use. A noncontacting "safety clip" opposite the sling prevents the mirror from tipping forward should someone tip the telescope below horizontal.

Under the mirror is an eighteen point stainless steel flotation cell. In *Telescope Making #26*, David Chandler describes his computer program for cell design. He was kind enough to run my optical parameters through his program and supply me with the calculations. The six triangles and three support bars were cut from 3/32-inch- and 1/4-inch-thick stainless steel, respectively. The connecting bars are supported by three 3/8-inch collimating bolts passing through threaded holes in the tailgate frame.

I epoxied a thin nut to each bolt for the bars to pivot on. The triangles and bars are loosely retained in their proper places by attaching the triangles to a 0.010-inch circular sheet of Mylar with tiny machine screws. (I couldn't find a glue that would stick to Mylar.) Mylar is great stuff. It's waterproof, lightweight, and impossible to tear. So you see, all of Dobson's original design considerations for supporting large, thin mirrors have been preserved.

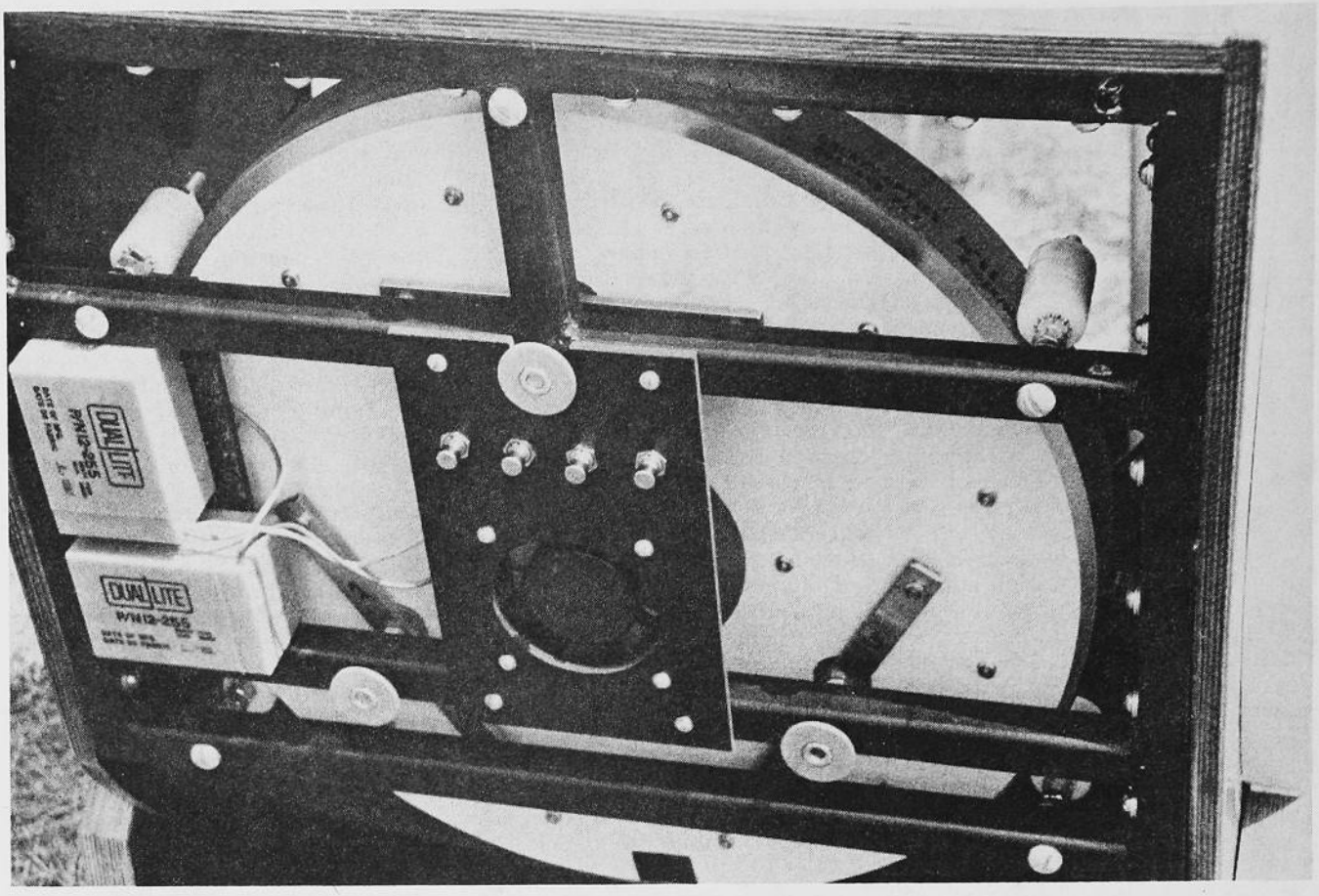
Eighteen 1-inch rubber washers were epoxied to the apices of each triangle and the mirror dropped in. It remains in the box permanently and is not removed for transport. To eliminate a collimation wrench, I epoxied a large nut and washer to the end of each collimating bolt for an easy grip even with a mitten on.

The whole works rides on an open framework tailgate fabricated from welded 1-inch-square steel tubing. I chose an open box bottom to allow for better air circulation to enhance mirror cooling after set up. The open tailgate, ultrashort box, and 12-volt muffin fan blowing air through a large hole cut in the center of the Mylar get the glass equilibriated very quickly.

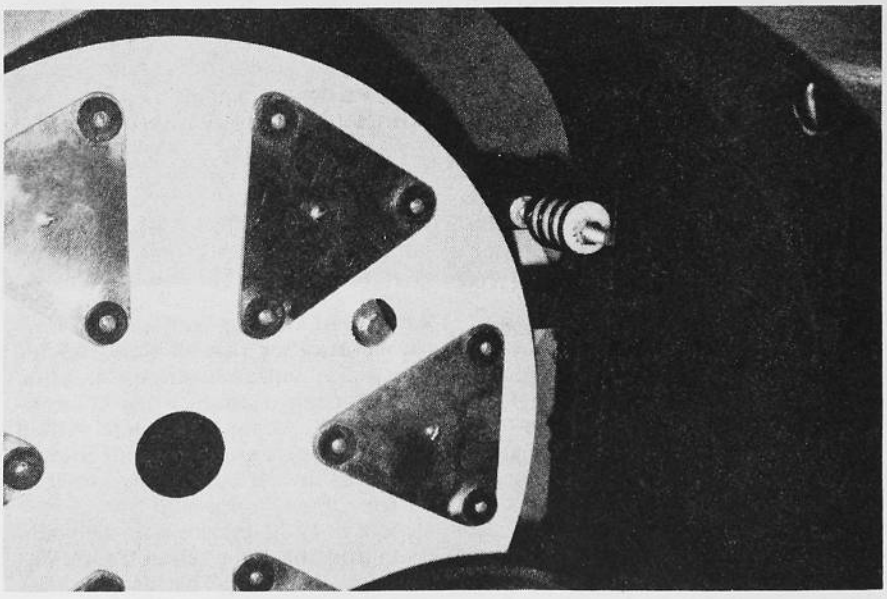
Bearings

The ease of motion of my telescope probably gets more positive comments than any other aspect. To achieve this, I paid particular attention to the bearings. The altitude bearings are 26-inch-diameter cast-aluminum semicircles. My good friend Dave Adamec happens to be a pattern maker in a foundry and it is to him that I owe all of the aluminum castings. I decided on 26 inches because that was the largest size possible, placing the wood pattern diagonally in the foundry's biggest flask, which was 20 inches square.

The two identical bearings were cast separately. At the time I was having these bearings fabricated, the telescope was nearly completed. On more than one occasion my wife had remarked that I was obsessed with it, so Dave cast the name *Obsession 1* into the bearings. Nice



Adopted from John Dobson's original design, a sheet of Mylar supports the elements of an 18-point flotation cell. Fan is for cooling the mirror.

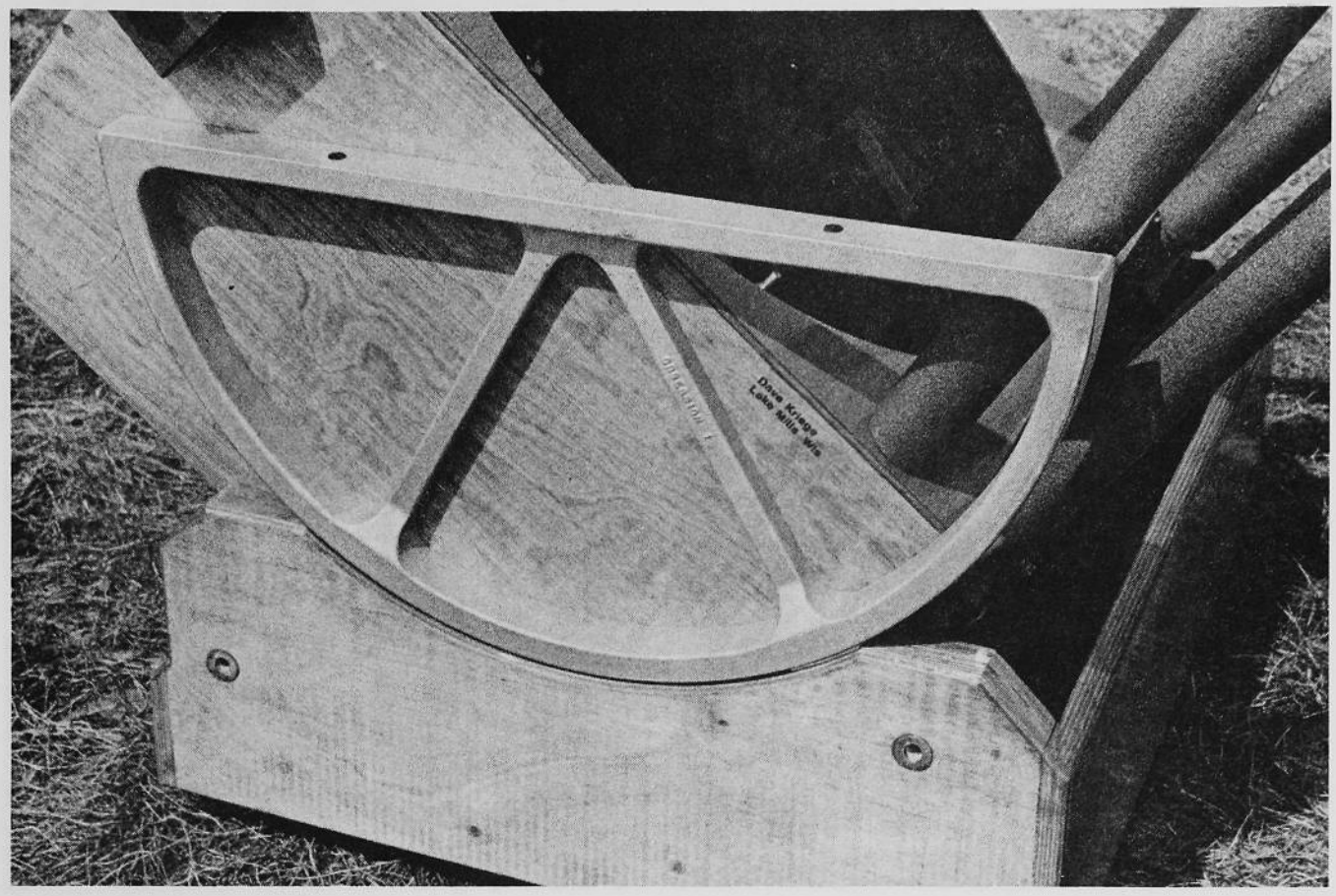


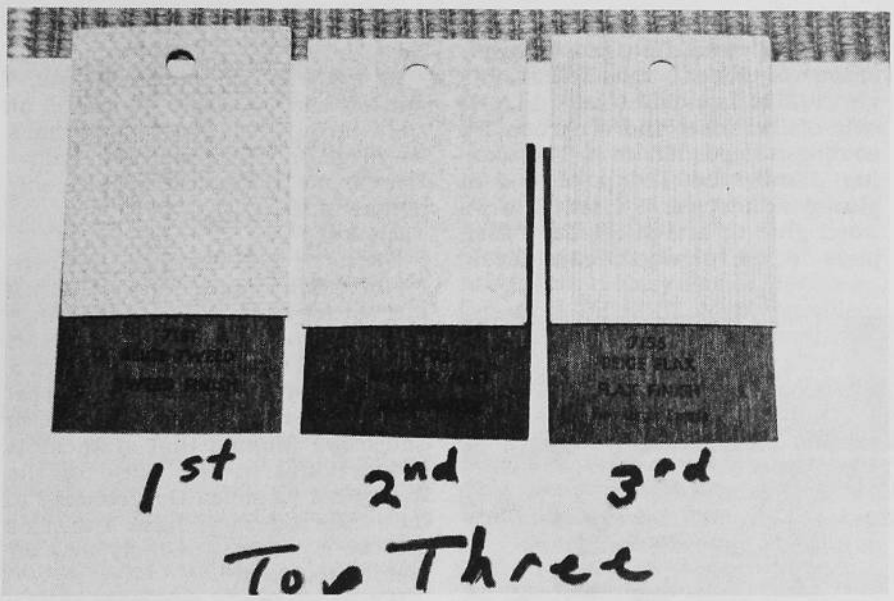
touch! After drilling a couple of holes through the diameters and bolting them together to form a 26-inch-diameter circle, the circumference was turned down on a big lathe. Drilled and tapped, the bearings were attached to the mirror box. Half-circle altitude bearings are more than adequate because the Teflon pads are set only 75 degrees apart.

Very large altitude bearings offer tremendous strength to the mirror box and substantially reduce the height of the rocker sides. More important, though, they increase the linear velocity of the bearing over the Teflon when following a star. The linear velocity should be "high enough for Teflon's regulating effect to occur, and the buttery feel characteristic of Dobsonians" attained. In a big telescope with a big moment arm this is a significant engineering requirement. Richard Berry's article "How to Control Friction in a Dobsonian Telescope" in *Telescope Making #8* was the basis for all my bearing research. Besides, large bearings look sexy.

The azimuth bearing is 20 inches in diameter and centered under the rocker with three 2.5-inch-diameter pads of virgin Teflon set 120 degrees apart. Number 7181 Beige Tweed Formica brand laminate was applied to *both* the rocker bottom and the altitude bearings with contact cement. After duplicating Berry's ramp test on every type of synthetic surface I could find, I've come to the conclusion that #7181 is unmatched with virgin Teflon for that easy buttery feel.

I'm not exaggerating when I state that it requires only two pounds of force to move the 175-pound telescope in either dimension at an





Huge side bearings, #7181 "tweed" Formica, and virgin Teflon make for smooth motion. #1795 "mist" and #7156 "flax" are the runners-up.

altitude of 45 degrees. By grasping the outer cage ring with my right hand, I can point the telescope in both axis simultaneously almost up to the zenith.

This didn't happen by chance. Equalizing the aiming forces in both directions was my goal from the start. The radii of both bearings would have to be similar, with the radius of the azimuth bearing a bit less because of the added weight of the rocker and the decreasing moment arm when approaching the zenith. This would also solve the critical linear velocity requirement, that is, making both bearings travel over the pads at the same rate. All that was left to "play with" was reducing the angle "theta" of the altitude bearings until the forces matched.

The first time I put all the pieces together I was quite surprised to find my telescope required about 1.5 pounds of force more in altitude than azimuth. I had to decrease theta to 75 degrees and put Formica on the altitude bearings too. I highly recommend this Formica/Teflon combination to anyone wishing to dramatically increase the performance of his mounting.

The #7181 has a very high profile stippled texture. It's the best of the laminates I tested and it's much better than any nylons or plastics. For some reason that someone will explain to me someday, the top five surfaces I tested out of about thirty all had a very "bumpy" surface.

Apparently there are two grades of Teflon, virgin and mechanical. Virgin Teflon—as the name implies—is pure and has never before been used. Mechanical Teflon is a mixture of old recycled Teflon with some new virgin Teflon.

The rollout and setup procedure for this 20-inch f/5 Dobsonian is a one-person operation. Twin ramps from the van side door opening accomodate bolt-on "wheelbarrow" mirror-box carriers; rolling the 150-pound assembly into the van is easy—it takes only about 75 pounds to lift and roll it. The ground board remains attached to the rocker box. Poles are inserted into the split blocks, and then secondary cage is dropped on and locked into place with quick-release clamps. The entire operation takes less than ten minutes start to finish.

During processing the old recycled Teflon never fully melts to form an homogeneous mixture. As a result, particles of recycled Teflon stick out of the mix, making it feel rougher.

Theoretically both Teflons have the same coefficient of friction but the virgin Teflon beat the mechanical Teflons I tested.

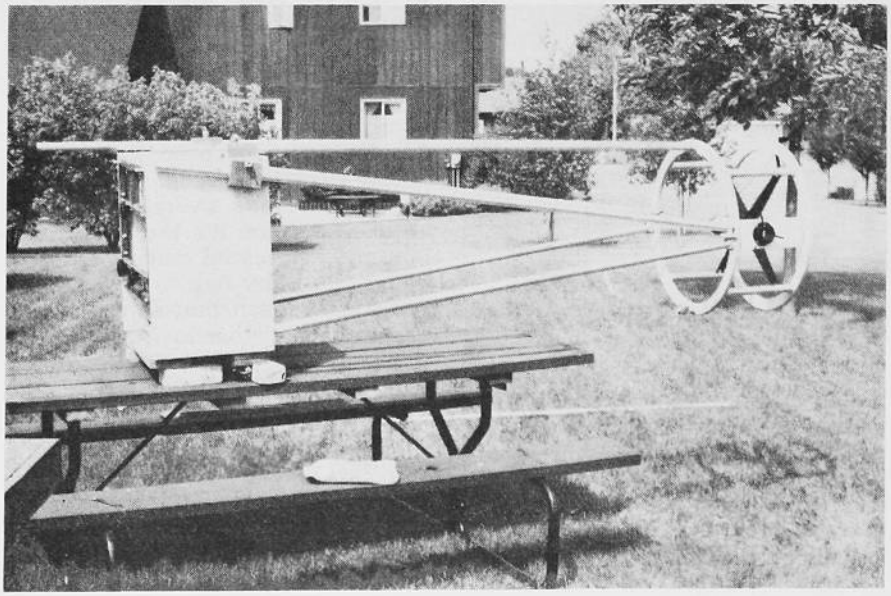
Another interesting Teflon I ran across and used throughout my telescope is etched virgin Teflon. Virgin Teflon is acid-etched on one side of the sheet and a carbonized coating is deposited on it. The coating allows the Teflon to accept gluing adhesives. I used Elmer's wood glue to attach all the Teflon pads to the plywood, eliminating nail heads that might scratch the Formica.

In addition, I must confess, I rubbed silicone white grease on all the bearing surfaces. I know that's sacrilegious, but it seems to help—there is no "stop-stick" with it—only a more "buttery" feel.

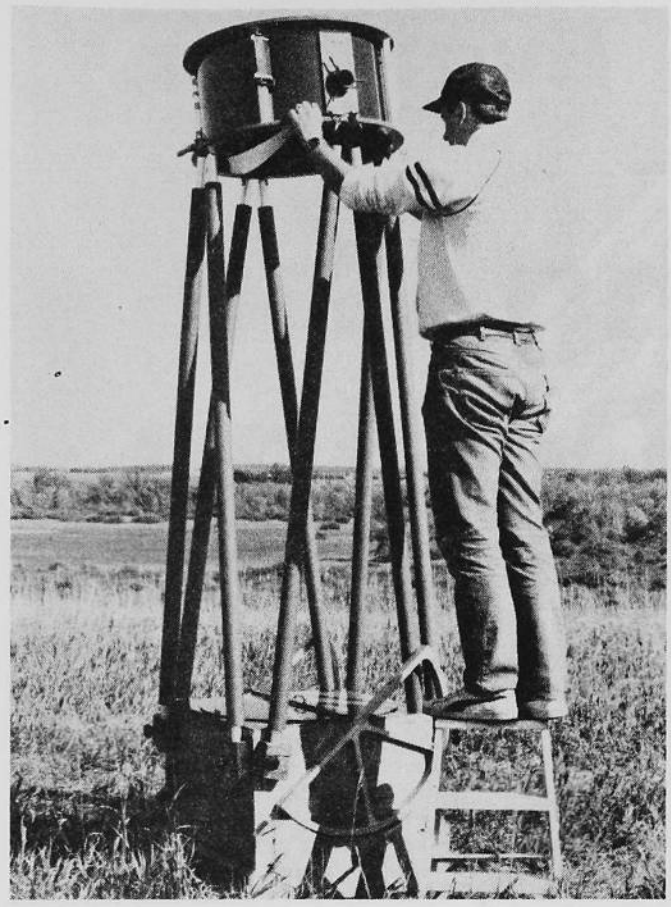
Rocker

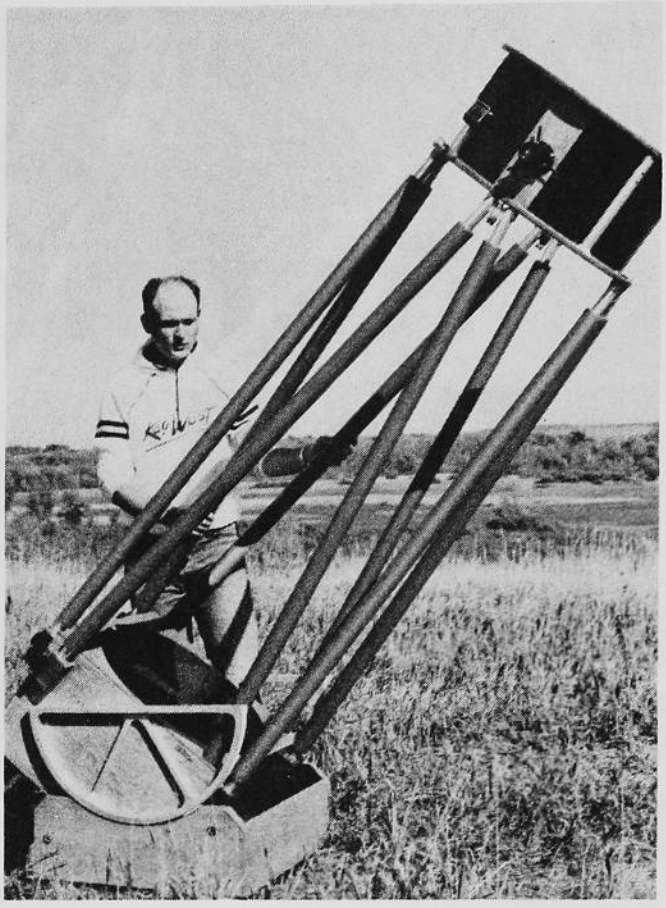
The large side bearings, low center of gravity, and reduced mirror box corner allow the center of rotation to be a short 17 inches above the rocker bottom, which yields a very low profile rocker and great rigidity. Having read somewhere in *Telescope Making* that stiffness is proportional to the cube of the thickness, I applied that concept to the rocker sides and base. The sides are two layers of 3/4-inch plywood bonded together.

The base I made extremely stiff by cementing a 1.5-inch layer of styro-



Initial alignment of the pole seats and wedges is important for proper operation. After two days of fussing with blocks, wedges, and poles in the garage, the first trial assembly was a success. Note the lightness of the tube structure—the balance point lies just above the mirror box.





foam in between two layers of 3/4 plywood. The resulting 3-inch thick foam core sandwich is eight times stiffer than two layers of plywood alone but without the extra weight. This is significant because it's in the rocker base that most of the flexure occurs when large telescopes are turned in azimuth.

It may all look strange, but it works great. When I follow an object the telescope responds instantly, and when I let go, the image remains in the center of the field. There is no rebound or memory from component flexure.

Mobility

The mirror box and the rocker, with its attached ground board, are all picked up together using wheelbarrow handles. The handles connect quickly to the rocker sides with protruding bolts and are retained by ropes and tensioners similar to a tent's "guy lines." With 10-inch air-filled lawn mower wheels on one end and me on the other, the entire lower assembly is rolled about easily. A couple of 2x6 wood ramps allow me to roll it in and out of my van by myself.

Finding Parts

You can find Baltic birch plywood in specialty woodworking tool shops or cabinet shops. I obtained virgin Teflon and Mylar sheeting from Midland Plastics of Milwaukee, WI, (414) 781-6520. The silicone white grease that gives that great "buttery" feel is Lube-a-Stick from Panef Manufacturing of Milwaukee, WI, (414) 464-9150.

The cam levers cost $1.87 each from Quik-n-Easy Parts, Monrovia, CA, (818) 358-0562. Methyl methacrylate plastic, or denture acrylic, is a material with great potential for making small parts. Fricke Dental Manufacturing of Villa Park, Illinois carries it—(312) 833-2627. The cast-aluminum altitude bearings and pole seats aren't available—they were special order. Everything else I purchased from the Ace Hardware store in Brookfield, Wisconsin.

Operation

The telescope is just plain fun to use. Optically it's a "Wow" scope. For a good explanation of what it's like to observe with a 20-inch reflector, see "The Lure of Big Telescopes" in the October 1988 issue of ASTRONOMY. I must disagree though with the author's assertion that anything larger than a 13-inch is a "two-person telescope." As my article and pictures show, big telescopes can be made manageable and "one person." In fact, I'm thinking of building a 32-inch some day along similar lines if I can figure out how to get up to the eyepiece.

Spontaneous observing sessions are my favorite, and the best nights are when the sky is clear and I'm in the mood. After driving to my dark site five miles away, setup only takes a few minutes. Collimation is remarkably stable. More often than not, no "tweaking" is necessary, even when I check it with a Cheshire eyepiece. The motions are easy and super smooth. Sweeping starfields *easily* with one hand on a 20-inch is a thrill that can't be described. Even beginners have no trouble following objects once they figure out the field reversal.

In summary, evolving Dobsonian technology allowed me to build a big telescope that's a pure delight to use. I spend more time observing now than I ever did when I was younger. My only regret is that I wasted twenty years indoors.

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Dobsonian Evolution

—

Refining the Basic Design

What crowd is this? what have
we here!
we must not pass it by;
A Telescope upon its frame,
and pointed to the sky.
—William Wordsworth

Background

I have been an amateur astronomer for over thirty years and, like many long-time observers, I have had a number of telescopes, beginning with a mediocre 2.4-inch altazimuth refractor I used in grade school. Didn't everybody? The small refractor showed enough to whet my interest and allowed me to independently "discover" Mars, Jupiter's moons, Saturn's rings, and several multiple stars and star clusters.

During my teenage years I often visited the home of Frank Mosher, a local amateur astronomer who held public star parties each clear Wednesday and Friday night. Working with telescopes ranging from a 6-inch refractor to a 16.5-inch Newtonian, this retired school teacher spent untold hours showing off the beauties of the night sky to anyone who would come and look. It was through him that my interest in large telescopes began to grow, and I knew my small refractor would soon become a telescope of the past.

Being in no position to purchase or make a large telescope at the time, I elected instead to build a 6-inch f/8 Newtonian. I did much of the work on the mirror but in the end opted for a refiguring job by a professional. The telescope turned out well, and I remounted it several times over the years. Even today, over twenty-five years later, the optics and tube fittings are still in use by my brother-in-law, Bob Scholtz of Columbus, Indiana. (Bob and I work closely on building telescopes, and after the rebuilding of my 17.5-inch, he rebuilt his 12.5-inch with the same general design.)

My only adventure with a "large" telescope came several years later when I had the opportunity to purchase a professionally built 8-inch f/15 refractor. The instrument was of excellent quality but had one major flaw. It was so big that when I moved to another community, the telescope had to stay behind. (I have since sold it to a science museum in the northeast.)

Because I couldn't always drag a large telescope after me as I moved about, I began to think I would have to be content with a small telescope if I planned to do any observing at all. It was then that I acquired a 3.5-inch Questar, an instrument that has always performed exceptionally well. I expect I will always keep the Questar, and were I asked to choose a single telescope as my only optical instrument, it would probably be the one.

The Dobsonian Connection

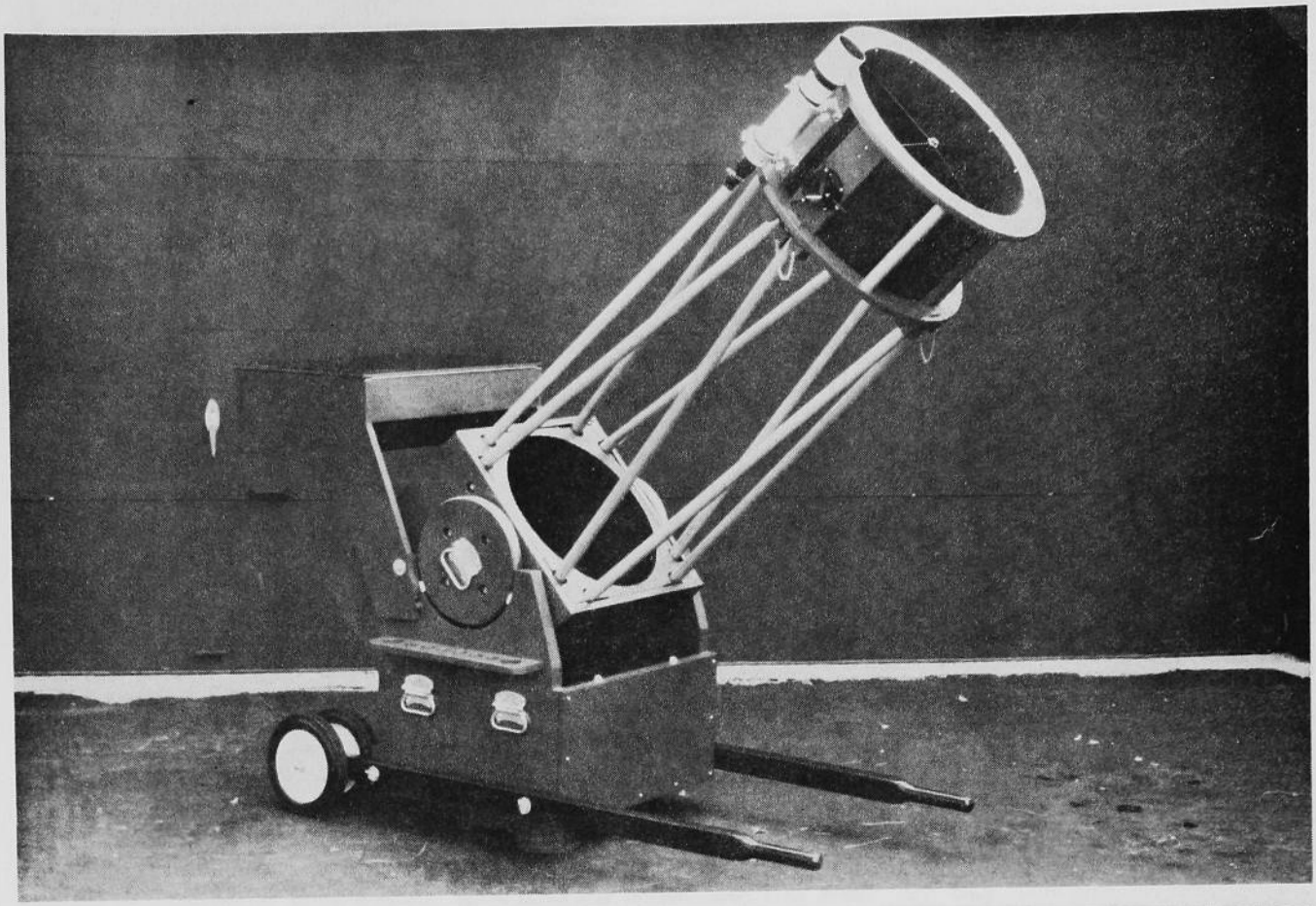
The story of my odyssey from telescope to telescope might have ended with the Questar, had it not been for an article in the June 1980 issue of ASTRONOMY that described a novel method of building a 10-inch reflecting telescope. The article pointed out the ease with which one could make a portable, large-aperture "Dobsonian" telescope. It could be built inexpensively and was so foolproof it would work in spite of the workmanship put into it.

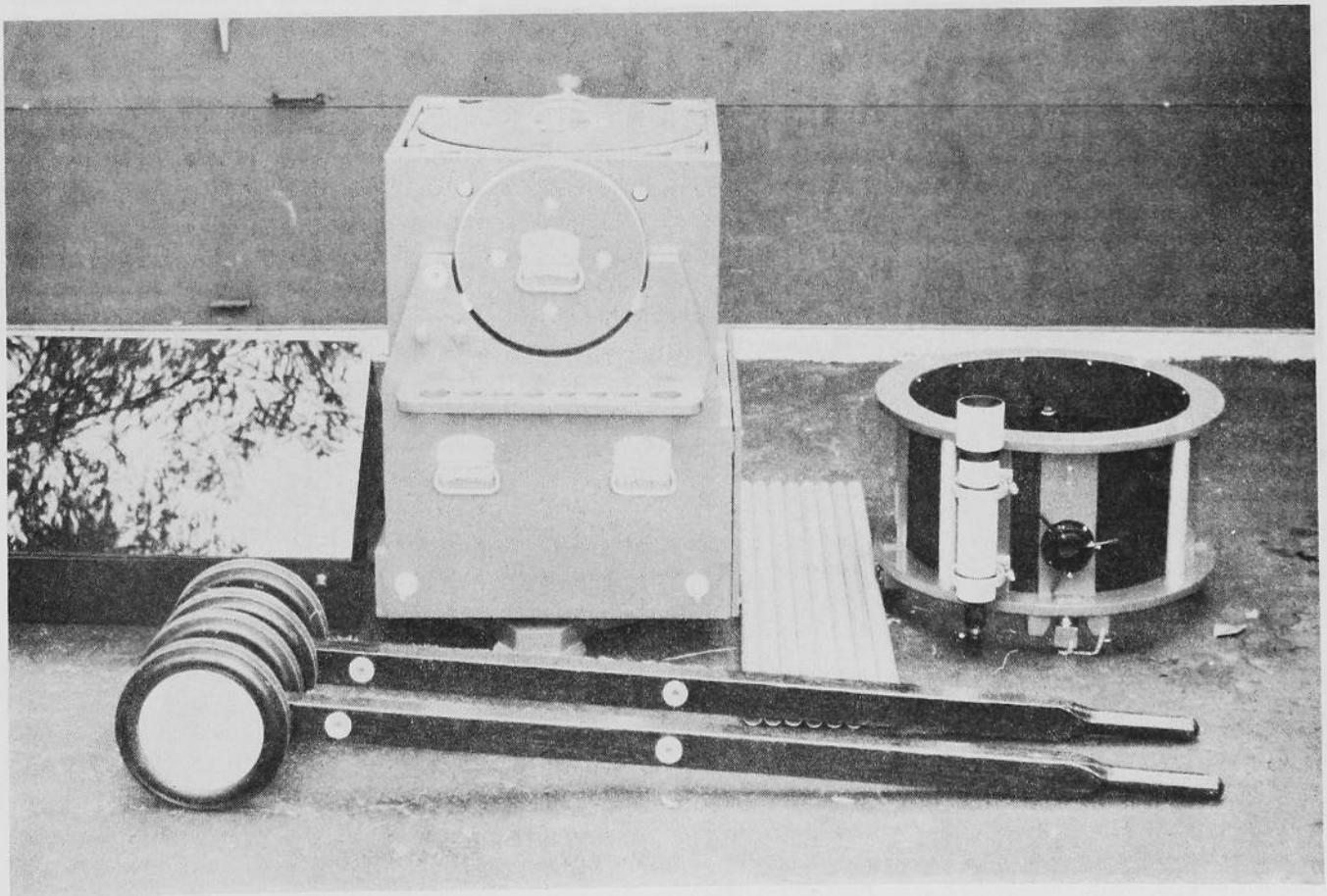
And so I decided to go ahead and build the 10-inch described in the article. That is, I intended to until I noticed an advertisement for Coulter Optical Company in the same issue offering a set of 17.5-inch Newtonian optics for less than $600. The deal seemed too good to pass up, so I immediately ordered a set and sent Coulter a deposit.

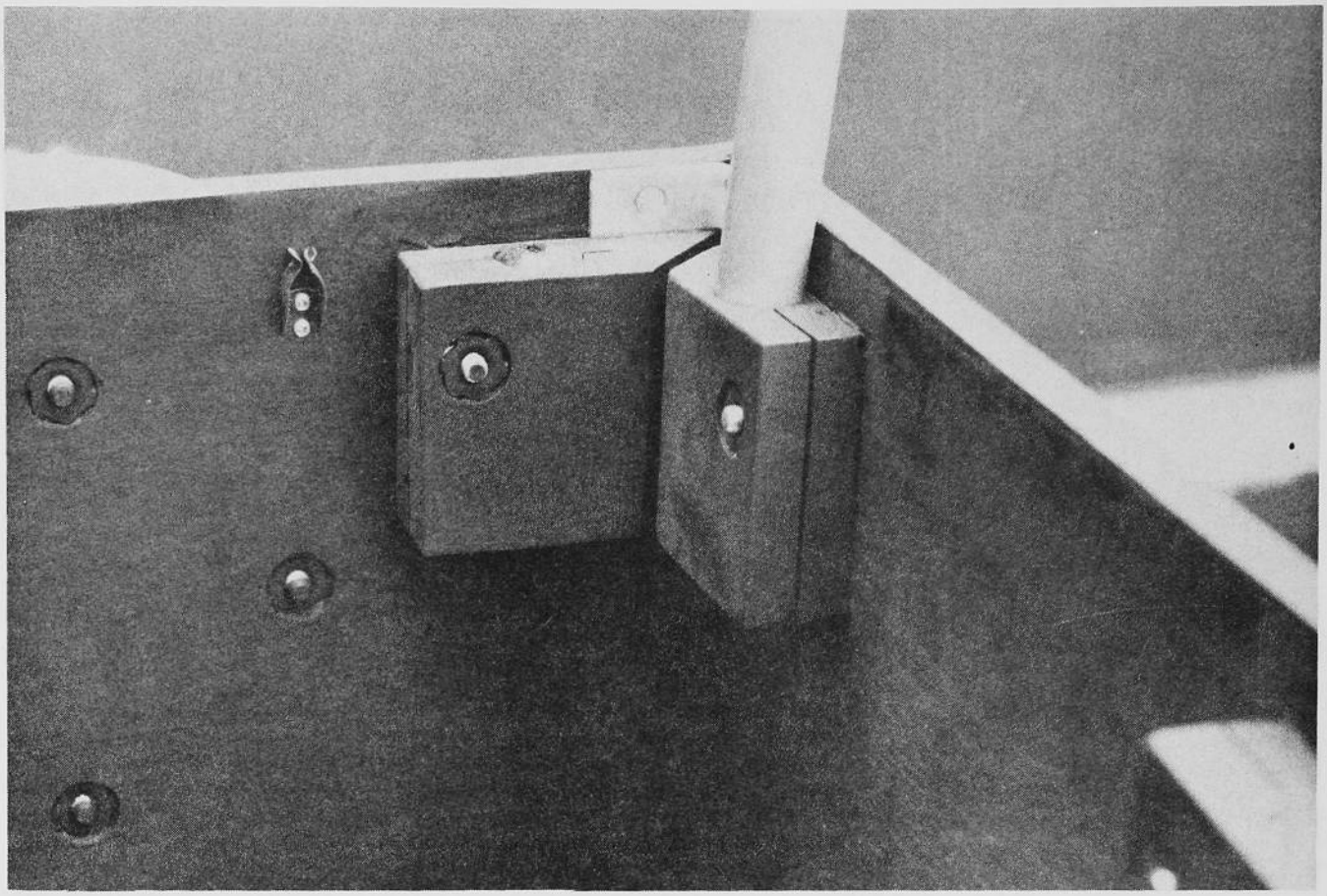
Having been told that delivery on the optics would be between ten and twelve weeks (it actually took eight months), I began to read everything I could find about Dobsonian telescopes so I could begin the construction on the telescope itself. I have listed the primary resources I found (and have located since) in the References section. They provide the reader with the basic principles of Dobsonian design and construction and are "must" reading for anyone planning to build a Dobsonian telescope.

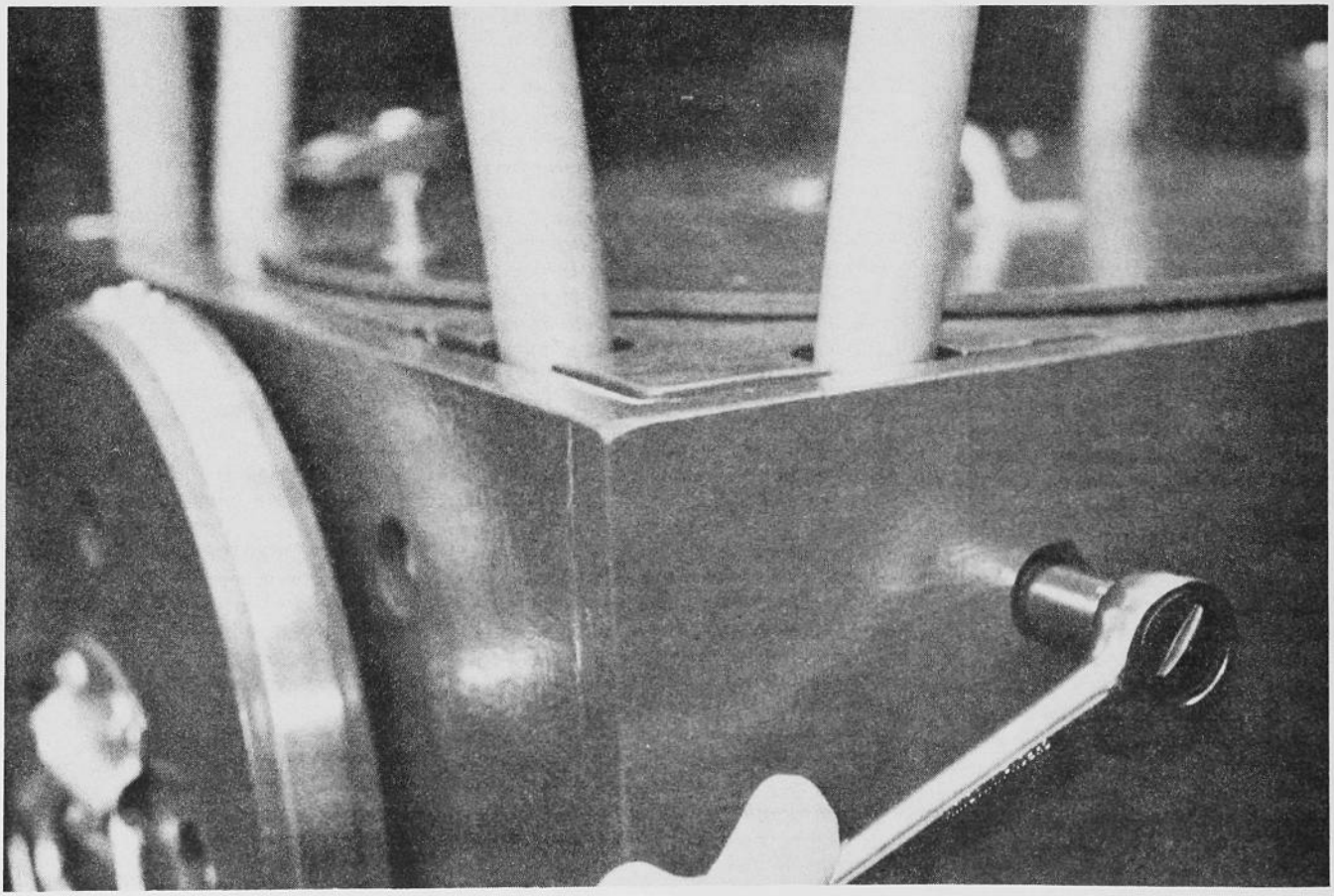
My plan was to make a telescope that would be easy to use and interesting in appearance but that would not vary significantly from the basic principles of Dobsonian design. I describe the specific problems I encountered and solutions I developed in that process in this article. I can claim little originality in my telescope, as most design solutions are hardly more then variations of ideas developed by other amateurs.

"Rooster-tail" Dobsonians offer the observer greater portability, functionality, and ease of use than big-telescope designs of five years ago.









But as Albert G. Ingalls stated in his introduction to *Amateur Telescope Making*, "It is not . . . unsportsmanlike to study closely the details of telescopes made by others and to 'lift' this or that feature from them, provided one improves these features."

Original Design

My original telescope was a traditional Dobsonian, except that I used a hexagonal tube made of plywood instead of following the usual box-and-sonotube approach. That first telescope served me well until the spring of 1987, when I replaced it with the one described herein.

Why did I change telescopes? First, because my original Dobsonian was too big to take out of town and conditions at my usual driveway observing site had deteriorated to where I simply wasn't using the telescope. Second, the original telescope never performed the way it should; images were poor even after Coulter refigured the mirror.

Building for the Future

So I decided to rebuild the telescope and try to get it to work the way I wanted. In redesigning the instrument I worked with the following goals in mind:

A Better Mirror The telescope needed to form better images than the original. Enter Dick Wessling. At the 1986 Apollo Rendezvous I spoke to Richard Wessling, a Cincinnati-area amateur telescope maker and professional optician. Dick is familiar to many amateur telescope makers. He is well known for his high-quality optical surfaces and compound optical systems. (His 20-inch thin-mirror Dobsonian was described in *Telescope Making #14*, page 32. One of his more recent projects, a 12.5-inch Buchroeder Schiefspiegler, was featured as the cover article in *Telescope Making #28*, page 32.) Dick had already refigured one Coulter 17.5-inch primary for fellow Columbus amateur Tom Burns, and he agreed to look at mine. (Tom's "ultraportable" 17.5-inch is described in an article he co-authored with Dick Suiter for *Telescope Making #19*, page 18.)

What he discovered was that even after having been refigured by Coulter once, my mirror was still only 50 to 80 percent corrected, depending upon the zone that was being measured. It also had a "rough" surface, but that could be expected in a fast-production optical surface. After the review he agreed to remedy both the undercorrection and the surface irregularities.

Mirror-box clamps hold the truss tubes tightly without crushing them. One 3/8-inch socket wrench serves for all adjustments, including this.

Optimal Performance Because I was starting from scratch (the only items carried over from the original telescope were the mirror blank supporting the refigured surface, the ground board, the finder, finder rings, and my eyepieces), I decided to do everything possible to make the telescope's performance everything it could be. That meant evaluating the entire system, including optical supports, the diagonal, the focuser, and anything else that came to mind.

Stability My original telescope had performed like a classical Dobsonian, providing the smooth, backlash-free motion for which the design is known. I wanted the same "feel" for the new one, even if that meant I would have to make some sacrifices in the areas of size and weight.

Portability The new telescope not only had to be better than the original instrument, but it also had to be portable. Not that I wanted to be able to fold the instrument up and put it in my wallet, but I at least wanted to get the whole thing into a station wagon with room left over.

Ease of Use The telescope had to be easy to set up and use. I had grown lazy with my original instrument, which could be rolled out of my garage and ready to go within three minutes. Because assembly would be required whenever I moved the telescope from my home, I wanted a design that would go together in under five minutes, would not require extensive collimation in the dark, and would not have any loose knobs, bolts, or wing nuts to fumble with cold fingers and drop onto the ground (or the mirror!).

Appearance As Louis Sullivan said a century ago, "Form . . . follows function." In other words, make a telescope that works first, and then make it attractive. Thus, once the above five criteria were addressed, I would be free to design a telescope that would also look good. Appearance was important to me because, given the climate of central Ohio, I would probably spend more time looking at the telescope than through it. I guess times have changed since the days of Joseph von Fraunhofer. Once when he was chastised for cosmetic imperfections in the glass of an objective lens, he responded that the lens "was made to be looked through, not at." Fraunhofer obviously didn't live in Ohio.

The Serrurier Truss Solution

After mulling over many telescope designs that would meet the criteria I established, I finally decided to go with some form of modified Serrurier truss. The Serrurier truss, named after Mark Serrurier who developed the design to control tube flexure in the 200-inch Hale telescope on Mount Palomar, has been around for several years and has lately become quite popular for large amateur telescopes.

Two events firmed up my ideas for the telescope. The first was when I saw Ivar Hamberg's portable Dobsonian design. (Ivar's telescope is described in *Telescope Making #17*, page 4.) I felt as if I'd uncovered one of the secrets of the universe. Hamberg's telescope was little more than a low rocker, a short mirror box, a lightweight truss, and a short diagonal cage. Yet it put the power of a 17.5-inch telescope in a small, one hundred-pound package.

The second was a review of the design and dimensions of the "Very Portable Telescopes," manufactured by Sky Designs on Colleyville, Texas. The Sky Designs approach seemed to address most of the shortcomings I saw in Hamberg's design and produced an attractive "transportable" instrument (as opposed to Hamberg's "portable" design). In other words, you could get the whole telescope into one car, but you wouldn't want to carry it very far to set it up.

I was ready to begin.

Construction Materials

My telescope is built primarily of plywood and required tools no more sophisticated than an electric drill, a circular saw, and a paint brush. Such simplicity of construction was important for two reasons: I am not an accomplished builder, and I don't have very many tools or a well-equipped shop.

Other ATMs did help me with the occasional use of a radial arm saw (for cutting the Serrurier truss tubes and the aluminum for the flotation cell triangles), a drill press (for drilling the truss tube mounting blocks), a band saw (for some general cutting), and a router (to cut the groove for the aluminum band on the altitude trunnions).

I did not skimp on construction issues related to the strength or permanence of the telescope; all

connections were glued and screwed, and I used dowel pins to provide extra strength where appropriate. The side boards, bottom board, and ground board of the mount are fabricated of two thicknesses of 3/4-inch plywood. I used exterior plywood throughout and coated it with Thompson's Water Seal and a polyurethane base paint for extra moisture protection.

In building the second telescope, I worked with a certain respect for "finish." Unlike my original telescope, on this one I actually used some wood filler and sandpaper. While it is not equivalent to the wooden masterpieces of other telescope makers such as Steve Rismiller, at least in the dark my telescope looks as nice as any other. (Steve's beautiful walnut telescopes can be seen in *Telescope Making #18*, page 8; *TM#21*, page 26; *TM#22*, page 40.)

Mirror Box

The mirror box is 21.5-inch square and 24 inches tall and made of 3/4-inch plywood. The bottom of the box is double thickness. All joints are glued and screwed for extra strength and the front corners are braced with angle brackets.

Front Baffle I placed a removable front baffle plate on the mirror box to restrict the ambient light that might strike the mirror. The baffle also improves the appearance of the telescope and covers the corner blocks that hold the Serrurier truss tubes. Cupboard door clips hold the baffle in place, which allows me to remove it without any tools.

Mirror Box Cover I also built a plywood cover to fit over the opening in the baffle to keep dust (and dropped tools) off the primary mirror. Spring-loaded clips that can be rotated around the underside of the baffle hold the cover in place. The cover can't fall off, yet it requires little effort and no tools to install and remove.

Centering Pads To keep the box centered in the rocker and to minimize any friction and abrasion when moving the telescope in altitude, small Teflon pads are attached on each side and the front of the mirror box inside the rocker.

Mirror Cell

Because I wanted to leave the primary mirror in the telescope during transport, I used a full mirror cell instead of the traditional Dobsonian sling mount. I modeled the cell after the one Richard Berry made for his 20-inch; Berry's cell is pictured in *Telescope Making #7* (page 24) and detailed in *Telescope Making #8* (page 39).

Cell Design The body of my cell is an octagon made up of two layers of 3/4-inch plywood. Above the body is a ring of plywood that surrounds the mirror. The rest of the cell consists of another plywood ring separated from the first ring by eight 3/4-inch-thick spacers roughly 1.5 inches in diameter. The spacers are drilled slightly off center and 1/4-inch bolts pass through the top ring, the spacers, and the cell body where they screw into T-nuts.

The off-center drilling allows me to rotate the spacers into light contact with the mirror to prevent side motion in the cell. Once the bolts are tightened, the spacers are held tightly between the two rings.

Four tabs padded with felt keep the mirror from falling forward when I point the telescope near the horizon. Handles on four sides of the finished cell make it easier to lift out of the box for mirror cleaning.

Flotation System A nine-point flotation system supports the mirror. The triangles are made from 1/4-inch aluminum and "float" on the heads of cap nuts. The mirror rests on the heads of nylon screws in the corners of the triangles.

Cell Adjustment The cell is adjusted with a push-pull system of 3/8-inch bolts that can be adjusted with the same socket wrench used to assemble the Serrurier truss. The "push" bolts bear against mending plates attached to the back of the cell; the "pull" bolts screw into T-nuts mounted in the cell body.

If you've made a telescope carefully, you only have to change two adjusting bolts to collimate the primary mirror; the third can remain fixed. Therefore, I placed the adjusting bolts in an equilateral triangle with one apex on the bottom, leaving easy access to the top two bolts for collimation. If the two bolts were on the bottom, I would have had to reach inside the rocker and under the telescope to get to them.

Transporting the Mirror I always leave the mirror in the cell; the mirror is not removed when I transport the telescope. The whole mirror box assembly may be heavier that way, but the mirror is as safe as can be and never gets handled during normal use.

Diagonal Cage

I made the diagonal cage from two 19.1-inch inside diameter, 2.25-inch wide rings of 3/4-inch plywood held together by five (one to support the finder) 10-inch-long plywood spacers. In addition, I inserted four lengths of leftover aluminum tubing between the rings and passed 1/4-inch thread rod through the rings and the tubes. The rod ends were then secured with self-threading nuts. The aluminum tubes provide additional compression and strength and make excellent handles for grabbing the cage, both on and off the telescope.

Weight Considerations Because my telescope has a relatively heavy mirror box and large side bearings that resist slipping, it wasn't necessary to build an "ultralight" diagonal cage. This was fortunate, because I had already decided the finder needed to be mounted close to the eyepiece. Thus, I built the cage to be both strong and rigid, with weight as a secondary consideration. With smaller telescopes the weight of the diagonal cage is more critical.

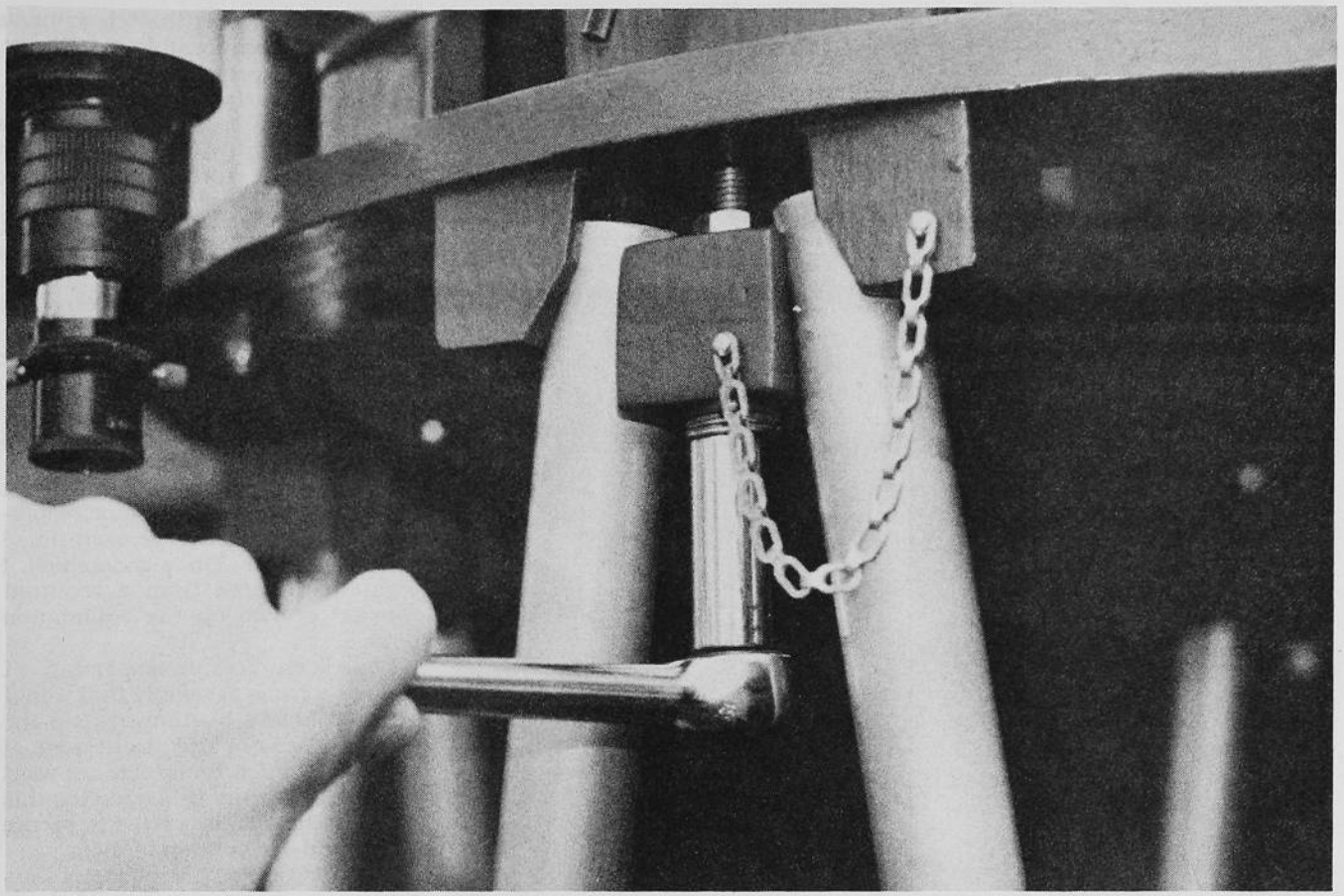
Light Baffle I covered the inside of the cage with thin aluminum flashing obtained from a hardware store. Because my focuser is only 4.5 inches from the base of the cage, I extended a portion of the baffle on the opposite side of the cage an additional 2 inches below the cage to block stray light from entering the focuser. (To achieve more complete light baffling, Bob Scholtz made the cage on his 12.5-inch telescope 18 inches tall with the focuser mounted 9 inches from either end.)

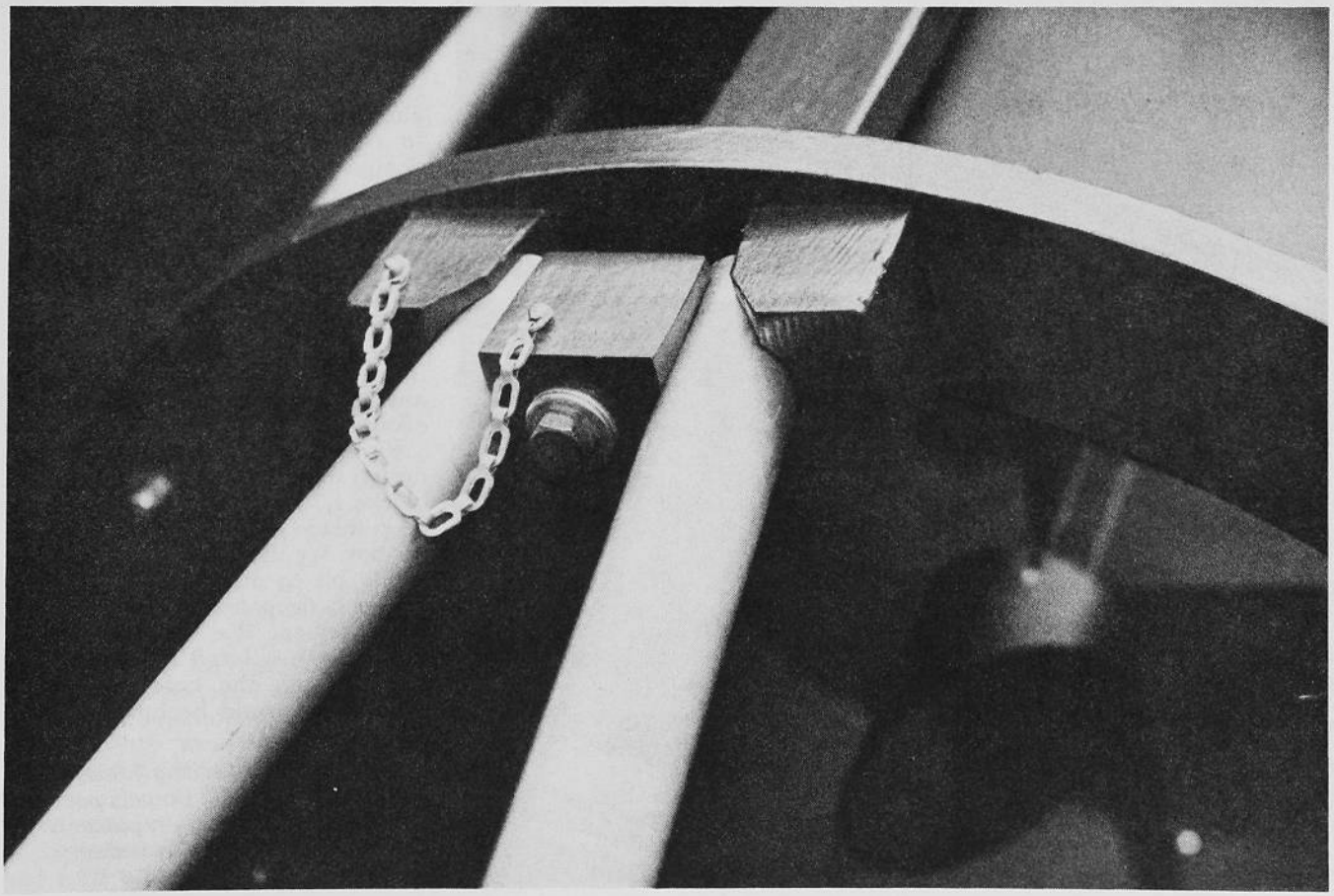
I had originally intended to make a fabric tube to wrap around the truss, similar to the one made by Michigan amateur Doug Nelle and shown in *Telescope Making #25*, (page 20). However, external light has not been a major problem and it doesn't seem necessary. When the weather gets colder, such a cover may yet be needed to keep warmer air currents from the observer away from the optical path.

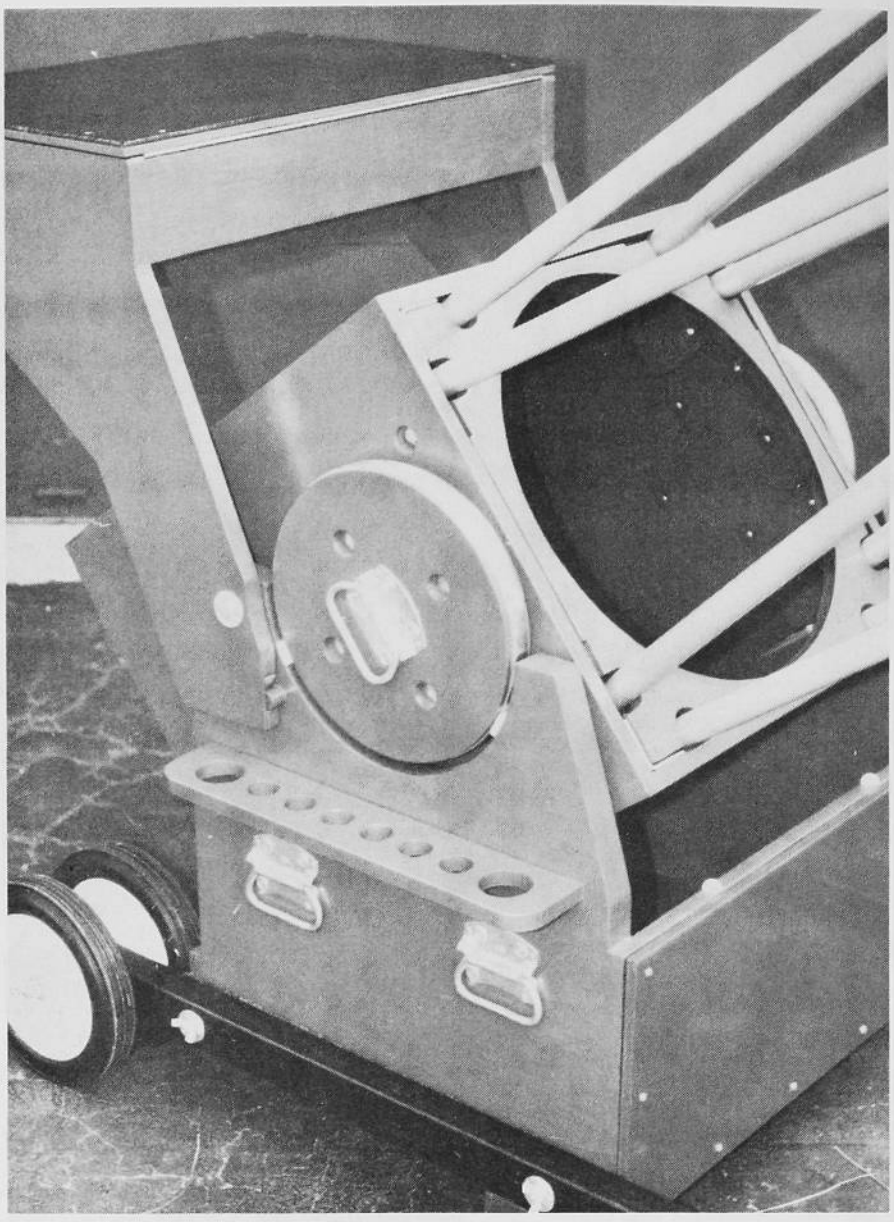
Serrurier Truss

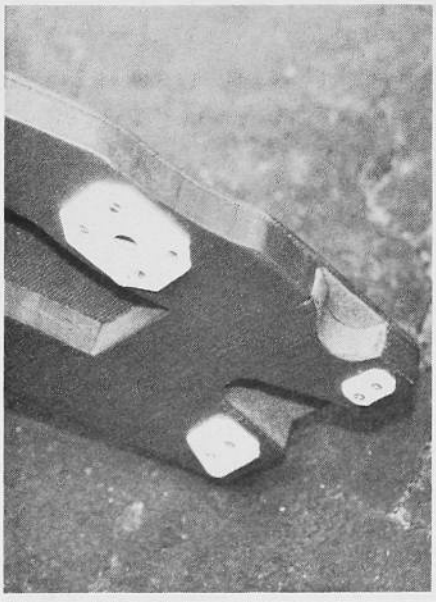
I spent a lot of time thinking of ways to build the Serrurier truss. Most of the similar telescopes I had seen described used a truss of lightweight aluminum tubing with flattened ends drilled to fit over studs attached to the mirror box and diagonal cage where they were secured with bolts or wing nuts. While such a design would be simple, it didn't offer what I wanted. In keeping with

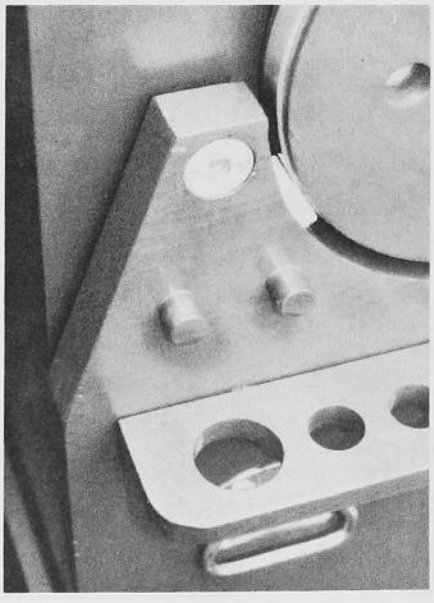
These diagonal cage clamps provide a positive grip on tubes—but don't get lost. Standard socket wrench does every job on the telescope.











Attaching the observing table takes just a few moments. Dowels position it; bolts snug it firmly in place. Note wheels for barrow-style transport.

my goal of making the telescope as easy to use as possible, I had several other objectives in mind:

No Loose Parts As much as possible, I wanted to avoid loose parts during assembly (they invariably get lost). That ruled out extra bolts, washers, wing nuts or special tools.

Interchangeable Components I wanted to make sure the truss tubes were interchangeable. Because on other telescopes I had seen, the tubes weren't the same, and the owners had to index particular tubes to specific holes and assemble the instrument exactly the same way each time - a procedure that can get complicated in the dark.

Minimal Recollimation I didn't want to have to do a major recollimation on the telescope each time I put it together. Once assembled, I wanted no more than a required "tweak" or two on the collimation bolts.

Easy One-Person Assembly I wanted a truss assembly that would be rigid before I attached it to the diagonal cage and tightened it down. I most certainly did not want a lot of aluminum tubes waving this way and that while I tried to secure a diagonal cage on top of them.

Clamping versus Mechanical Connectors As with most of the difficult design issues that came up while making the telescope, I once again worked with Bob Scholtz on the truss. Bob and I tried on paper almost everything we could think of to come up with a good truss design—all to no avail. Then it occurred to us to change the method of attaching the truss tubes from mechanical fasteners to pressure clamps.

From that point it was easy. At least thinking through the solution was easy, and the solution was "obvious" once formulated. But like anything worthwhile, it took a lot of effort to make it work.

Mirror Box Clamps In the final design we placed pairs of hardwood blocks 1.75 inches thick by 4 inches deep inside each corner of the mirror box. We used a drill press and a spade bit to drill the blocks with 3.5-inch deep holes to accept the truss tubes. We then split the blocks with a band saw from one end through the hole to form a clamp that could be tightened on

the tubes. One side of the block was then glued and screwed to the inside of the mirror box and a T-nut was inserted in the other side. The T-nut can be tightened with a recessed bolt on the outside of the mirror box.

The placing of adjustment blocks inside the mirror box does not work as well for telescopes with smaller mirror boxes, as the blocks soon begin to obstruct the optical path. Bob Scholtz used the same design on his 12.5-inch but required a mirror box with 19 inches sides, only 2.5 inches less than my 17.5-inch. One could still place the blocks outside the mirror box, but if the blocks are placed on the sides of the mirror box, the design might necessitate a larger rocker.

Because the tubes go from inside the mirror box to the outside of the diagonal cage, the holes in the blocks formed compound angles. Trying to drill them with the equipment we had was difficult, and the results weren't very successful. To make everything work, we finally decided to hand-fit the blocks with a plane and a sander. In other words, we just kept at it until everything worked.

Diagonal Cage Clamps On the diagonal cage, each pair of tubes fits between two hardwood blocks shaped to fit the tube diameters. A third block wedges between the tubes and bolts into a T-nut attached to the cage. The connecting bolts are permanently installed in the wedge blocks and have washers and lock nuts on the tops of the blocks to press the blocks out when the bolts are removed from the cage. Without the lock nuts, the wedge blocks can be difficult to remove. With the lock nuts to force the blocks out, unscrewing the bolts slips the blocks out as easily as could be. I also placed small plates over the T-nuts to keep them from being forced out while unscrewing the bolts. The wedge blocks themselves are connected to the cage with small chains so nothing can ever be dropped or get lost.

Adjustment Bolts All assembly bolts are 3/8-inch hex head and are adjusted with the same socket wrench used for collimating the mirror cell. Because there are no small parts, all adjustments can be made while wearing gloves, an important point during Ohio winters.

Truss Tubes The truss tubes are 1.25-inch diameter aluminum tubing with a 0.058-inch wall thickness. I was a little concerned about stability of smaller and thinner tubing, so I picked the larger size. I located the tubing at an industrial materials supply firm and purchased three 12-foot lengths for the project.

Many suppliers have a $50 or $100 minimum order for aluminum tubing, so shop around and talk to several of your friends into making telescopes too, or else you'll have to pay the whole amount yourself. The less expensive aluminum tubing usually available at your local hardware store may be too soft and may not have sufficient rigidity to do the job. Bob Scholtz built his 12.5-inch Dobsonian with wooden closet rod instead of aluminum tubes. It seems about as sturdy and is slightly heavier but significantly cheaper.

Interchangeable Tubes The secret of repeatability of collimation upon reassembly is making the truss tubes interchangeable; they must all be the same length and have square ends. Once I've collimated the telescope, it should remain collimated upon reassembly, irrespective of which truss tubes are placed in which holes.

To ensure tube accuracy, fellow Columbus amateur John Masters and I set up a cutting jig on a radial arm saw and cut the tubes with a carbide blade. All that was required to finish the tube was to burr the cuts with a file and clean the protective coating off the outside surfaces with steel wool and "Soft Scrub" cleaner.

What I ended up with is a Serrurier truss that assembles very easily. The tubes are simply dropped into the mounting holes and the clamping blocks are tightened a turn or two. I then set the cage on top of the truss and the wedge blocks are inserted and tightened with the same 3/8-inch socket wrench.

As it has turned out, the maintainability of collimation is very good. I have disassembled the telescope, transported it several hundred miles, and reassembled it without having to change a thing; all center spots on the mirrors remain concentric and the finder cross hairs stay right on target. The most the telescope has ever required upon reassembly is a slight adjustment of the top two mirror cell adjusting bolts and a slight realignment of the finder.

Altitude Bearings

One of the main "secrets" of the Dobsonian design is the careful selection of bearing materials; the combinations I used were Teflon/Aluminum for altitude and Teflon/Formica for azimuth. I purchased Teflon from a plastics supply firm and found Formica and aluminum at flooring and hardware stores, respectively.

Bob Scholtz used Teflon-Nylon for the azimuth bearing on his 12.5-inch because of the small difference between static and kinetic friction in such a combination.

Design The side bearings are quite large (12 inches) to provide proper friction for comfortable observing. They are made of dual-thickness 3/4-inch plywood banded with 1/8-inch-thick aluminum and ride on 1/4-inch-thick Teflon pads. A force of three to four pounds moves the telescope in altitude.

Before assembly, Columbus amateur Jim Pace and I routed a 1/16-inch-deep groove in the edges of the trunnions to accept the aluminum bands. The groove allows the aluminum to be secured at the ends alone (thus keeping the bearing surface smooth), yet prevents the band from shifting during use. I originally built a bending template out of scrap plywood, but I soon discovered that the easiest way to shape the aluminum bands was to bend them by hand and then fit them to the plywood trunnions.

Because the aluminum bands were attached only at their ends and weren't completely tight around the trunnion, they would sometimes creak and groan like an old ship when I moved the telescope in altitude. I remedied the problem by removing the bands and wrapping several layers of PTFE Thread Seal Tape around the trunnion before replacing them. The tape slightly increases the diameter of the trunnions to tighten the bands and provides low friction surfaces so if the bands shift, they slide silently instead of seizing. All is now quiet.

The curves that support the altitude trunnions are cut directly into the tops of the telescope's side boards instead of into separate cradle boards mounted inside the rocker. The result is a more attractive instrument and a narrower rocker (not a trivial issue in a telescope of this size).

Finding the Balance Point I determined both the location for attaching the side bearings and the inside dimensions of the rocker by laying the assembled tube assembly (including optics, finder, and eyepiece) across a broomstick to find the balance point. In my case the

tube balanced 6 inches from the front of the mirror box. Thus, a 12-inch bearing would be flush with the mirror box, hence my choice of that size bearing.

The side bearings are attached to the mirror box with four 3/8-inch bolts screwed into T-nuts inside the box.

Rocker Design

The side and bottom boards of the rocker that support the telescope are made of two thicknesses of 3/4-inch plywood for added strength. The front and back boards are single thickness.

The finished rocker is 25 inches wide and 23.25 inches deep, including the front and back boards. The pivot point for the altitude bearings is 27 inches above the ground. The rocker's inside dimensions are just adequate to nest the mirror box for compact transporting. When vertical clearance isn't as critical, the mirror box is left in its normal position with the altitude bearings riding in the cutout arcs.

The rocker is significantly smaller than the one for the original telescope and only takes up about two thirds the space. While the new telescope is more compact than its predecessor, the maximum eyepiece height is greater because of the smaller diameter tube. However, I can still reach the focuser at any point using a simple two-step folding ladder.

Ground Board

Traditional Dobsonian literature has advised building a square ground board with three feet and offsetting the centering bolt or extending one footpad to center the telescope over the bearing. I have never understood why one should go to all the trouble to build a design that leaves unsightly corners visible when the telescope is pointed in most directions.

The ground board of my telescope is made of two thicknesses of 3/4-inch plywood and has a circular center section and triangular extensions resting on circular 3/4-inch plywood feet. Had I not installed the idler pads described below, even the circular center section would have been unnecessary. The triangular ground board is lighter than a square one, has shown no signs of warping, and is as stable as one could ask.

Azimuth Bearing

Azimuth bearings on Dobsonian telescopes traditionally have been made of Formica sheets gliding on Teflon pads. Although references in telescope-making literature have indicated that smooth, shiny Formica would not give the best performance, until recently no one had seriously tried to find the best materials available.

Dave Kriege of Lake Mills, Wisconsin, tested various Teflon and Formica combinations for friction before building his 20-inch Dobsonian. He found that virgin Teflon and Formica finish #7181 "Beige Tweed" offered significantly less friction than all other combinations. As a result, both the altitude and azimuth axes of his two hundred-pound telescope move with roughly two pounds of force.

Teflon comes in two varieties - virgin and reprocessed. Virgin Teflon is the first casting of the resin and contains no impurities. Reprocessed Teflon is made of remelted resins from previous uses and may contain impurities. Either will work for telescopes, but virgin Teflon will ensure the smoothest possible motion.

The azimuth bearing in my telescope consists of three circular 2.125-inch diameter by 5/8-inch-thick virgin Teflon pads screwed to the top of the ground board at 120-degree angles around the center. I picked circular pads because some other amateur telescope makers have reported circular pads have smoother start up than rectangular ones.

The pads are mounted 8.5 inches from the centering bolt, which gives a bearing outside diameter of 19.25 inches, roughly the same as that of the mirror (a good rule of thumb). By moving the pads in or out, friction can be increased or decreased slightly to "fine tune" the azimuth motion.

A sheet of Formica #7181 is attached with Weldwood contact cement to the bottom board. A 1/2-inch centering bolt passes down through the bottom of the rocker and through the ground board where it is secured with a nylon thread lock nut. Pointing the bolt down keeps the inside of the rocker clear and allows the mirror box to be nested inside the rocker without having to detach the ground board.

No provision for changing the bearing friction is necessary in a telescope this size. The motion of the Formica moving over the Teflon is smooth, vibration-free, and without backlash. With the telescope pointed upward at a 45-degree angle, movement in azimuth requires a force of roughly five pounds.

Idler Pads To keep the telescope from tipping off the main Teflon pads when observing near the zenith, three smaller Teflon pads are installed between the main pads. These idler pads are lowered so the Formica does not touch them unless the telescope begins to tilt off the main pads.

Floating Pads I also placed washers between the main Teflon pads and the ground board to allow the pads to rock as necessary to stay in complete contact with the bottom board, irrespective of surface irregularities or any eventual warping of the ground or bottom boards.

Observing Table

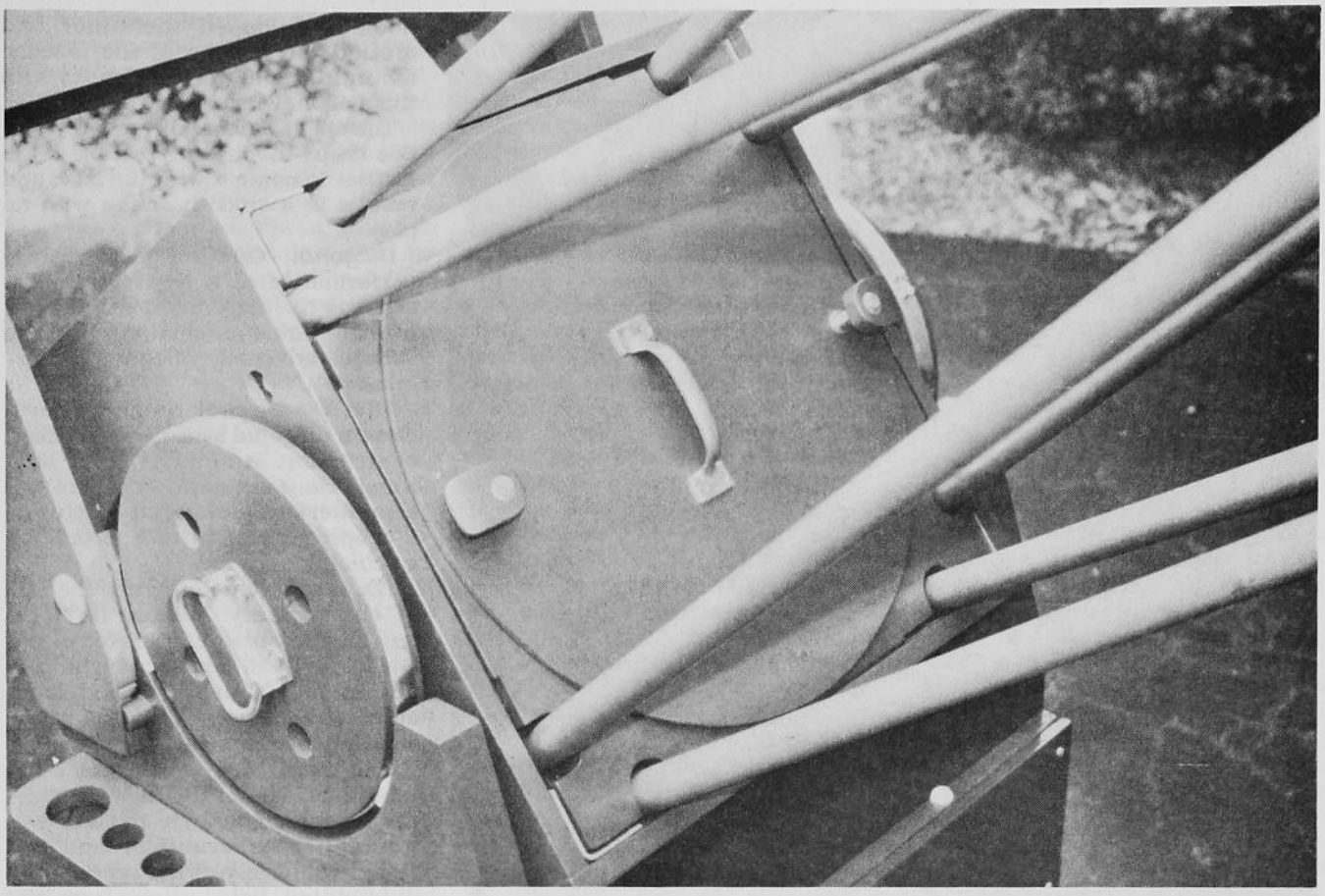
After using the telescope for several months, I decided to add an attached "observing table" to hold charts and accessories. The idea of the observing table occurred to me when I went to a star party and saw a similar device on Columbus amateur Bill Burton's 17.5-inch Dobsonian. (Bill's telescope is pictured in *Telescope Making #32*, page 20, and his innovative computerized "setting circles" are described in the July 1988 ASTRONOMY, pages 71-75.) The observing table idea seemed so obvious that I was surprised I had not encountered it before. Such a table has several advantages:

Convenience The table contains everything needed for observing except a step stool. It provides dustproof storage for eyepieces and filters, a separate area for tools and flashlights, a "flip-up" chart box to hold the field edition of Wil Tirion's *Sky Atlas 2000.0* and Fred Klein's *The Visibility of Deep-Sky Objects*, a little-known publication that provides catalog information on deep sky objects arranged both by object type and by Tirion *Sky Atlas 2000.0* chart. (The table is also large enough to allow use of the new *Uranometria 2000.0*.)

Protection The table is completely enclosed to protect books and charts from wind and dew and has an enclosed area for permanent storage of eyepieces. The front door folds down and provides a fixed surface for setting flashlights and other loose accessories. The eyepieces can also be kept in the table for protection on especially frosty or moist evenings.

Proximity No matter where I point the telescope, the table is always in exactly the same location relative to the eyepiece.

Construction is of scrap plywood



Clean, functional lines characterize "evolved" Dobsonian designs. Note handy features such as the mirror-box cover and eyepiece rack.

and hardboard. The lid is covered with a piece of red Plexiglas acquired at Astrofest 1987 and connected to the table with a piano hinge. I have considered illuminating the interior of the table with LEDs, but have not yet found the right combination for the job. In the meantime, to illuminate the star charts, I will continue to shine a red flashlight through the Plexiglas cover, which works fine.

In keeping with my philosophy of building telescopes that require few, if any tools or extra parts for assembly, I designed the table to slip over two 7/8-inch dowels extending from each side of the telescope's rocker. The table rotates into a locked position and is held in place by gravity.

However, because of the cantilevered mass of the table, a slight image vibration was sometimes visible through the eyepiece. So I compromised and installed two bolts to tie the table to the rocker. The table can be installed or removed in thirty seconds with the same 3/8-inch socket wrench I use for telescope assembly and collimation.

I made three minor design changes to the telescope to accommodate the table's forty-pound weight. First, I shifted the rocker's centering bolt 1 inch toward the back of the telescope to help offset the table's weight. Second, I added a 1/2-inch-thick steel plate the same size as the front board to the front of the rocker to restore the telescope's balance over the centering bolt. Finally, to keep the azimuth motion smooth under the additional weight, I reduced the diameter of the azimuth bearing from 21 inches to 19.25 inches by moving the Teflon pads. Now, even after adding nearly one hundred pounds of table, accessories and steel counterweight, the telescope moves as smoothly as before.

In the short time I have used it, the table has proven to be a great aid to observing. Because everything is always handy, I spend more time looking for difficult objects. Frequent trips between chart and eyepiece are easy, and the charts stay dry. Likewise, on nights when I want to get only one eyepiece out to look at familiar showpieces like M42, I can do so with no hassle. But if I find something interesting, other eyepieces, filters, charts, catalogs, and a flashlight are only a few feet away.

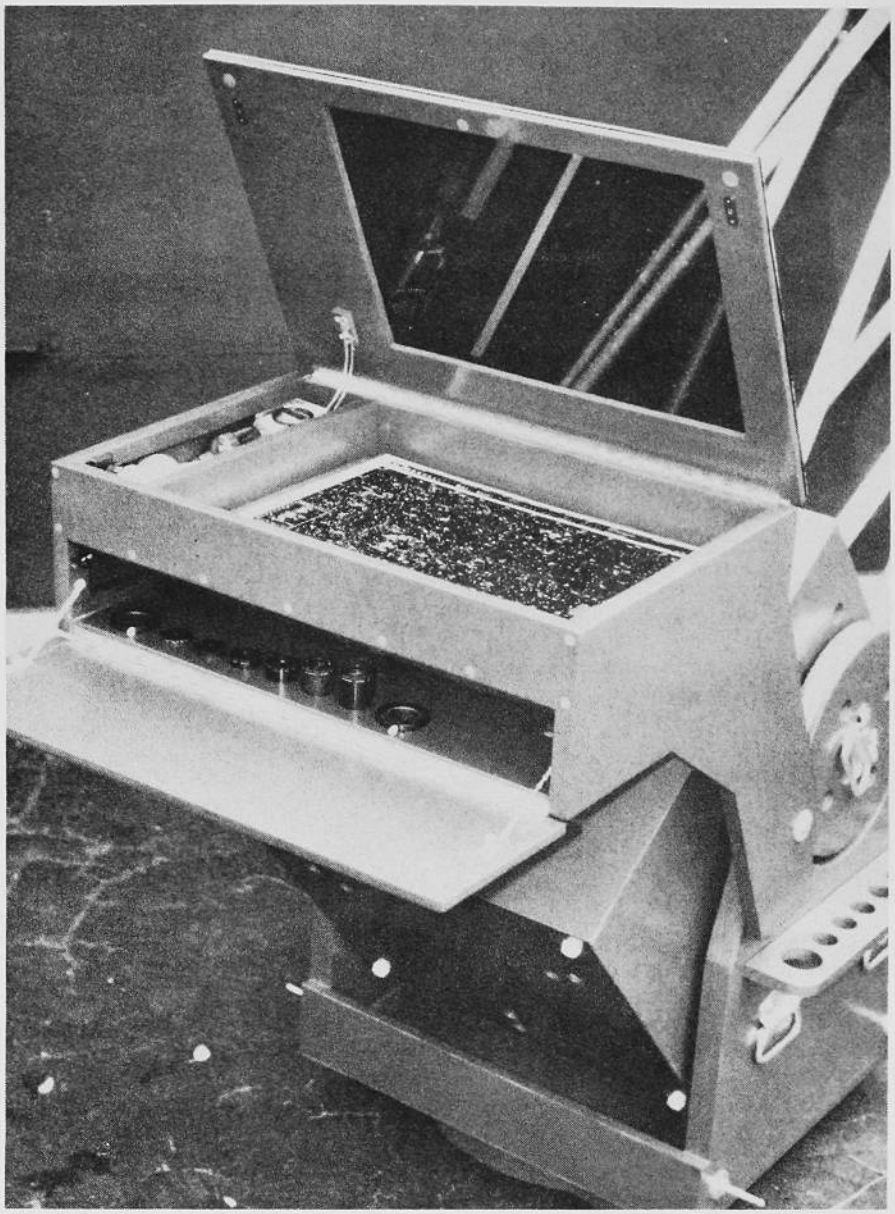
Miscellaneous Points

Possibly the best part about building your own telescope is that you can incorporate into the design the things you prefer in an instrument. When I designed mine, I recognized that it was, in fact, my telescope and should be built for my needs.

Some of the special considerations in my telescope are set forth below:

Eyepieces I have had a set of six parfocalized Brandon orthoscopic eyepieces for over twenty years and they have served me well with every telescope I have used during that time (except the Questar, which has its own set of Brandons). Their excellent correction, contrast, and eye relief have made me very fond of them.

My observing (left) eye is astigmatic, so I like to wear my eyeglasses at lower magnifications, where the eyepiece's exit pupil is large. (At higher magnifications the



Maps, eyepieces, flashlights, and other observing paraphenalia are always within easy reach with the "rooster-tail" observing table.

light pencil is smaller and the astigmatism isn't much of a problem.) With most of the new "wide field" eyepieces I can't wear my glasses and still see the edge of the field. However, if I take my glasses off, the image is astigmatic.

Therefore, there was little to gain by changing from my trusty Brandons to expensive Pretorias, Tele Vues, Naglers, or 2-inch eyepieces.

Focuser Even though I would not be using 2-inch eyepieces, I decided on a 2-inch focuser. I also wanted a short focuser to keep the telescope's diagonal size to a minimum. Because of the critical focusing demands of a short-focus Newtonian, I used Lumicon's low-profile helical focuser. The larger focuser also lets me insert a 48mm Lumicon Deep Sky or UHC filter into a 2-inch adaptor and leave the filter in the focuser while I change eyepieces. (I also have a separate adaptor without a filter, so I never have to screw and unscrew the filter in the dark.)

When mounted in a vertical position (as on the side of a Dobsonian), the Lumicon focuser has some play in the focusing tube. To remedy the problem, I drilled four small holes in the side of the focusing tube and added little hooks made from bent paper clips and shaped like peg board tool holders. I then attached one end of a small elastic band (the type used by orthodontists) to each hook and looped the other end around the portion of the focuser mounting bolt that protrudes into the diagonal cage.

The slight tension of the four elastics keeps the moving portion of the focuser in contact with the base and results in a smooth action with no play.

Diagonal One key factor in the performance of a Newtonian telescope is the diagonal size. I decided to make mine as small as possible without adversely affecting performance.

After poring over numerous articles on diagonal size, quality, offset, obstruction, and just about anything else, I sat down at a personal computer and developed a Lotus 1-2-3 spreadsheet to do the tedious calculations for me.

The model lets you enter the size of the primary mirror, its focal length, the outside diameter of the telescope tube, focuser height, and desired fully illuminated field diameter. It then gives back the major and minor axis measurements of an "ideal" diagonal. You can then enter the minor axis of the nearest standard size diagonal (or the size you would like to evaluate) and the model will give you the actual fully illuminated field, offset from the optical axis, measured offset along the diagonal's surface, and the percentage of the primary's aperture and area obstructed. You can also view graphs of magnitude loss and overall field illumination as a function of distance from the optical axis.

I finally decided on an E&W Optical 3.0-inch minor axis 1/20-wave quartz diagonal. The smaller diagonal (actually 2.88-inch clear aperture in its holder) reduced the primary mirror obstruction to around 16 percent of the diameter and less than 3 percent of the area. The light loss at the edge of a 1-inch-diameter field (the largest field stop on my Brandons) is 0.18 magnitude. With a medium magnification eyepiece, the magnitude loss drops to 0.05. Even at the edge of a 2-inch-diameter field, light loss is less than half a magnitude.

In other words, for all practical purposes light loss is negligible; the difference in brightness is simply undetectable in actual use. In any event, the increased surface accuracy of the new diagonal, coupled with the reduction in weight and amount of obstruction over that of the original 4.25-inch diagonal, more than makes up for any theo-

retical loss of light.

For astrophotography or variable star observing where field brightness is more important than weight, obstruction, or contrast loss, you should probably stick with large diagonals and fully illuminated fields.

In any event, if you're going to have a good diagonal, it should be mounted well. On my original telescope I built a spider out of shelf brackets and PVC pipe. It worked well but lacked the ease of adjustment I expected I would need for a telescope that would be assembled and disassembled frequently. So for the new telescope I got a heavy-duty spider and diagonal support from Kenneth Novak of Ladysmith, Wisconsin. It is, like other Novak products I have used, excellent.

Finder I equipped the telescope with a relatively large finder (Meade 9x60mm) to assist in locating objects in the "less than perfect" skies of my Ohio observing sites. I also made sure that the telescope would balance with the finder mounted on the diagonal cage, because it would have been inconvenient to use mounted anywhere else.

As in any telescope with a nonrotating tube, remember to orient the finder's cross hairs to match the axes of the telescope (e.g., vertical and horizontal in a Dobsonian). Then, when you bring an object into contact with one of the cross hairs, you can simply move the telescope along its other axis to center the object in the finder.

Eyepiece Rack Because the telescope is mounted on an altazimuth mount, it is feasible to place a rack to hold the six Brandons and two 2-inch adaptors on the instrument itself. The eyepieces are always immediately at hand and in the same position relative to the focuser. And, perhaps because of the immediate presence of the large, thermally stable mass of the plywood telescope, the exposed eyepieces usually remain free of dew or frost. On particularly "wet" nights the eyepieces can be kept in the observing table.

Handles There is no way to make a small 17.5-inch telescope; it's going to be big and awkward to move in spite of everything. To at least make it easier to lift, the telescope has large luggage handles on the mirror box and the rocker. Smaller handles, while less expensive, can dig into your hands and make moving the components very uncomfortable.

Right-Hand "Drive" The finder and focuser are placed on the leading side of the telescope (for viewing objects in the south), a decision made primarily because my left eye is dominant and I can more easily use the finder. One advantage of the Serrurier truss is that there is no telescope tube to get in the way and you can easily use the finder, no matter what your eye preference.

An additional benefit of this arrangement is that when observing in the southern portion of the sky, the primary motion for following an object is a pulling one with my right hand (I am also right-handed), which gives me slightly better control of the instrument than does a pushing motion.

Telescope Color I used dark red polyurethane paint on the telescope so the large amount of ambient light at my observing site would not reflect off the tube and damage what limited dark adaptation I may have managed to achieve. (My original telescope was dark blue for the same reason.)

Collimation Proper collimation is critical in large-aperture, fast—focal ratio telescopes. I use the Mirror Spots and Collimating Tube method described by D. Eric Allen in his article entitled "Updating Newtonian Collimation" in *Telescope Making #22*, page 4. The method is easy to do, obvious (once you get the hang of it), and yields considerably better images that I had been able to get using simple "eyeballing" techniques.

Printed Handout Last, but not least, I prepared a small handout containing the ten most frequently asked questions about the telescope (e.g., "How much will the telescope magnify?", "How far can you see with it?"), and brief, nontechnical answers. Anyone who isn't sure why I did this has probably never taken a large telescope to a public star party. One can only answer the same questions so many times and still make the responses sound fresh and spontaneous. Plus, the public always seems to like something to take home, and the handout serves that purpose well.

Storing and Transporting

The telescope is stored in a corner of my garage and is moved to the driveway or patio for most observing. I did not design the telescope for maximum portability (with resulting sacrifices in stability), because I knew from long experience that despite the murky skies in town I would use a telescope at home many times for each time I would transport it to a dark site. So, to allow the assembled instrument to be moved with minimal effort, I acquired two 5-foot wheelbarrow replacement handles and equipped each with two 10-inch lawn mower wheels at one end. (The larger the wheels, the easier it is to move the telescope over uneven ground.)

The handles attach to the side boards with wing nuts (keep an extra to replace the one you drop in the dark) and allow the telescope to be picked up and rolled from the garage to its observing site. The mounting bolts remain in place on the side boards but do not get in the way while using the telescope, as observers or visitors do not pass close enough to bump into them.

Once the instrument is set up, the handles are removed and set aside. I remove the dust cover, uncap the finder, set the eyepieces in the eyepiece rack, and the telescope is ready for observing (except for any time required to reach thermal equilibrium). Total time required for setting up the 17.5-inch is just under three minutes.

Performance

The telescope is a joy to use. The motions are comfortable and following objects presents no problem, even at higher magnifications. On most nights the telescope's primary mirror thermally stabilizes in about an hour. Because the optical system is quite "fast" (actually f/4.4), resolution at the edge of the field is not perfect. But when an object like M42 drifts into the field of view, theoretical textbook discussions of the relative merits of this or that optical system lose much of their importance.

Even though I observe from within the city limits of an area with a population of over a million and from a site illuminated by porch lights, passing cars, and the glow of a nearby airport, the instrument still performs remarkably well. The following observations are typical of a good night (5th-magnitude stars detectable with "averted imagination"):

M1 The Crab Nebula shows its S-shaped outline. Traces of filamentary structure can be seen with averted vision.

M13 The largest and brightest globular cluster in the northern sky is fully resolved at all magnifications (as are many other globulars). The nearby galaxy NGC 6207 shows up as an oval glow with a tiny stellar

core (actually a superimposed star).

M31 The Andromeda Galaxy comes into its own with the larger aperture. Multiple dust lanes become visible. The faint star cloud NGC 206 can be seen, as can individual globular clusters.

M42 The Orion Nebula extends across a low-magnification field. The dust lane cutting across the nebula appears darker than the surrounding background and gives the impression of being superimposed on the nebula. The blue-green color of the nebula is so evident that several individuals who had never before looked through a telescope commented on it. Mottling of the nebula's core is striking. All six stars in the Trapezium are visible at moderate magnification.

M51 The famous Whirlpool Galaxy easily shows off both components. Two spiral arms are visible surrounding the primary nucleus and the faint connecting bridge to the secondary nucleus (NGC 5195) can be traced along most of its length.

NGC 891 This large edge-on galaxy is beautiful. Under dark skies the narrow dark lane looks as if it were drawn with a pen and appears slightly scalloped along its edges.

NGC 4565 This edge-on galaxy extends across the entire field under medium magnification. The lane of obscuring dust is evident, and the fainter nuclear bulge is dimly visible across the dust lane.

NGC 6960/6992 Both major portions of the Veil Nebula in Cygnus can be seen as rivers of light extending across several fields of view. With the UHC filter in place, the impression is one of curling wisps of cigarette smoke.

B33 Under dark skies and through a borrowed Hydrogen-Beta filter, Orion's Horsehead Nebula appears as a black bay cutting into a stream of nebulosity. It's not easy to see, but it's there.

3C 273 The brightest of the quasi-stellar objects shows up as a dim blue star. Comparison stars more than a magnitude fainter are visible in the field of view.

Lunar and Planetary With the original telescope I had the best luck viewing objects in the solar system when I placed a 6-inch off-axis diaphragm over the front of the telescope. With the diaphragm in place, planetary views were outstanding. The new telescope hasn't had enough use for me to learn the limits of its performance, but early views of the planets without a diaphragm appear to be excellent.

Several months after the 1982 opposition of Mars I could still see the polar cap and many dark areas, and during the 1988 opposition the amount of detail visible was stunning. Saturn shows a wealth of detail, both on the disk and in the rings. Jupiter is as good as I've seen it in any instrument, displaying more cloud belts than can be counted. The four Galilean satellites can be seen undergoing eclipses and transits. I recently viewed one satellite in transit as a small white spot near its pinpoint shadow. The outer planets (Uranus, Neptune, and Pluto) are all easily visible in mediocre skies, but I haven't yet tried for any of their satellites.

The Moon displays great amounts of detail only glimpsed or guessed in some other instruments. For example, the craterlets in Plato appear as small craters raised above the floor of Plato and not simply as the white spots seen in smaller telescopes.

While some of the above observations may be routine for smaller telescopes in better skies, the fact that they could be made in central Ohio inside a major metropolitan area underscores the power of a 17.5-inch aperture.

Conclusion

Well, how did everything turn out? I started out with the criteria of better optics, better performance, stability, portability, ease of use, and appearance.

In fact, the optical performance of the telescope is much better then before. At 240x the stars in globular clusters are hard points with no spurious light. The instrument is every bit as stable and moves more smoothly than my original telescope. It all fits in the back of my station wagon. The telescope assembles in under five minutes and doesn't seem to lose much collimation from setup to setup. Finally, I like its looks, but others will have to judge for themselves.

Modifying the Dobsonian To the newcomer to the Dobsonian design, my telescope may appear to be very different than most other Dobsonians. Such is not the case. I restricted my design changes for the most part to cosmetic and non-critical areas of the telescope. A close examination will show that the main principles of the Dobsonian design such as matched bearing materials, large bearing diameters, short and rigid construction, and no cantilevered components (except for the observing table) still hold for my telescope.

I have seen and used a number of Dobsonian telescopes in the past few years. Unfortunately, few of them demonstrated the stability the design is capable of delivering. It seems that some telescope makers think that if they simply place a telescope on a plywood altazimuth mounting and throw in some Teflon and Formica at appropriate points, they have a Dobsonian telescope that will perform like the ones in the magazines. Not so. All of the things Russell W. Porter used to preach about overhang, small bearing diameters, and flimsy construction are as true with Dobsonians as with any other style of telescope.

The Dobsonian approach is successful because it works. Materials, dimensions, construction techniques, loading, and forces all play important parts in the design; the telescope builder who adheres to the basic "rules" of the Dobsonian will end up with a telescope that works better than it has any right to. The builder who arbitrarily modifies the basics in building his telescope is on his own.

Whither the Future?

The Dobsonian design (I understand that John Dobson doesn't even like the term "Dobsonian") has come a long way since the early telescopes of the San Francisco Sidewalk Astronomers. Materials and dimensions have been improved and optimized, tubes that were once simple Sonotube are now trusses of aircraft-grade aluminum, Teflon pads and Formica sheets have become circular pads of virgin Teflon and sheets of Formica #7181.

But is refining the Dobsonian approach the only way to go? It's important to keep in mind that the Dobsonian may not represent the best long-term design for easy-to-build large telescopes and that there may be better solutions waiting to be found. Simply refining the Dobsonian might be similar to trying to make the most accurate and easiest-to-use slide rule. Twenty years ago it made sense. Today, who cares?

Richard Berry recently commented to me that those of us who have been building telescopes for awhile may know "too much" to take the lead in the future of amateur telescope making. I agree. We might refine and improve existing approaches but are probably not destined to be originators of major design innovations.

The future is in the hands of the next John Dobson who is faced with design problems yet not burdened by traditional approaches and years of doing things "the old way." Dave Kriege may be typical of the new innovators. Rather than directly copying the work of others, he incorporated their design concepts, conducted his own materials research, and built what may be one of the most elegant (yet simple) portable 20-inch telescopes ever seen. Not a bad accomplishment for someone with little previous experience building telescopes.

References

The following sources were of great assistance to me in making my telescope. I would strongly recommend them to anyone planning on building a large Dobsonian.

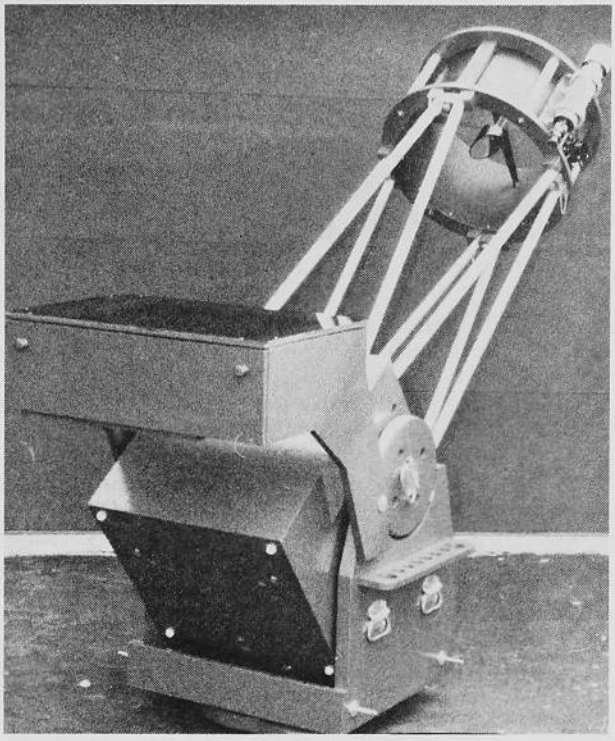
Telescope Making Almost every copy of this excellent quarterly periodical contains something of interest to the builder of Dobsonian telescopes. The citing of individual references would take too much space. Besides, such a list would take the enjoyment out of poring over the many issues in search of bits of information. You could certainly build an excellent telescope without these magazines, but I'm not sure why you'd want to.

Sky & Telescope (April 1980) This issue contains an in-depth review of the San Francisco Sidewalk Astronomers authored by John Dobson. Some of the guiding philosophies of the Dobsonian approach, if not the construction details of his telescopes, are included. In any event, an excellent article.

ASTRONOMY (April 1980) It must have been a good month for John Dobson. Appearing the same month as his article in *Sky & Telescope* was an interview conducted with him for ASTRONOMY. Although much of the information duplicates that in the other article, the style of the ASTRONOMY interview is quite different.

ASTRONOMY (June-August 1980) These issues of ASTRONOMY carried a fine series of how-to-do-it articles on making a 10-inch Dobsonian (since reprinted in *How to Build a Dobsonian Telescope* described below). While constituting a good "Insert Tab A in Slot B" set of instructions, the articles by themselves do not address many of the general principles and design guidelines as well as either *Telescope Making* or *How to Build a Dobsonian Telescope.*

How to Build a Dobsonian Telescope Now out of print, this publication, compiled primarily from reprints out of *Telescope Making*, also included the three articles from ASTRONOMY described above. This is probably the best single document available on Dobsonians and provides everything needed for designing and building one. Don't miss it!



Sky & Telescope (March 1977) In this issue is an article by William T. Peters and Robert Pike entitled "The Size of the Newtonian Diagonal." The article includes appropriate formulae for computing diagonal size, and magnitude and illumination loss as a function of distance from the optical axis. Peters also submitted a letter published in *Telescope Making #22* regarding downsizing of diagonals.

Build Your Own Telescope This straightforward approach to building five separate telescopes is an excellent resource for ideas and methods - even if you're not building any of the particular telescopes described. Published by Charles Scribner's Sons, New York City. The author, Richard Berry, is also the editor of ASTRONOMY and *Telescope Making.*

Sky & Telescope (January 1988) My telescope was described and pictured in the Gleanings for ATMs column. While the descriptions are not as extensive as the current document, the presence of a number of photographs make many of the construction details more apparent. The observing table was added after the *Sky & Telescope* article was published, so it does not appear.

What It's All About

Even with new materials and techniques, the true joy of telescope making will remain what it has always been - the fun of tinkering with a pile of raw materials and turning it into an instrument that shows the wonders of the universe to all who wish to see.

A large telescope is a powerful instrument that can be used for all types of observing, from timing the eclipses of Jupiter's satellites to following the fluctuations of fitfully slumbering variable stars. For me, however, a telescope is something more: it's a time and space machine that can transport me to places most of my fellow men don't even know exist.

A night spent ferreting out faint lights in a game of celestial hide and seek does much to ease the pressures of the modern world. Watching someone's reaction when first viewing the Moon, M13, or Saturn's rings through a telescope of mine makes me feel I have given that person something he will never forget and no one will ever be able to take away; he has for the first time seen his own universe up close. My telescope makes it possible; it is the one thing that makes me different from other people. I'm "the guy with the big telescope."

Robert Frost captured the same feeling in his poem "The Star-Splitter" where he said,

The best thing we're put here
for's to see;
The strongest thing that's
given us to see with's
A telescope. Someone in every town
Seems to me, owes it to the town
to keep one.

In Columbus, it may as well be me.

Ronald L. Ravneberg
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Dobsonian Evolution

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The Telescope Is Just One Part of an Observing System

The key to designing a big telescope is thinking of the telescope as only one part of an "observing system"—a system that includes storage, transport, and observing site. From the moment I decided to build my 17.5-inch scope, I knew I had to place emphasis on my ability to transport it to a dark sky. Like many people, I live in a light-polluted suburban area, so observing from my house would be a waste of the capabilities of my new equipment. Also, because I frequently do my observing alone, I would have to set up the telescope by myself. The system was further constrained by the fact that I would transport the telescope in a Honda Accord.

Fortunately, when I began construction of the telescope over four years ago, I had benefit of Ivar Hamburg's fine design in *TM#17*, plus some valuable ideas from a helpful Australian amateur named Stephen Patti. While the concept of building a telescope with removable trusses is not at all unique today—there's even a commercial builder now using this arrangement—it was then. These struts are the central element in my transportability equation.

When I completed it for the 1985 Texas Star Party, my scope weighed in at 135 pounds, including mirror and finder. Even though I had covered the scope in Formica instead of painting it (which added about twelve pounds), I felt I had accomplished my goal of a transportable instrument.

Conquering Dew

As anyone who has built one knows, telescopes are never really finished: they just stop evolving until necessity and the next burst of ambition come along. So it was no surprise that the next phase of the evolution of my telescope started very soon after it saw first light. After seeing Tom Martinez's fine Poncet platform at Astrofest in the fall of 1985 and enduring a very heavy dew while trying to be among the first to glimpse Halley—we were—I was convinced some additions and modifications were needed. Further use of the scope showed two other areas that required attention: a need for a quicker cooling of the primary mirror—because I often contend with 30-degree day-to-night temperature differential, and a means of collimating the system alone in the dark, which I often couldn't accomplish without two flashlights and three hands.

The solution to the dewing problems seemed to be the most critical issue. Even a perfectly collimated, thermally stable scope is useless with a fogged secondary. I found that the American Science Center had some inexpensive nichrome wire "heating ropes" about 30 inches long. These warm just slightly when 12 volts DC is applied. I spiraled one against the back of my secondary mirror and tacked it to the glass with silicon cement.

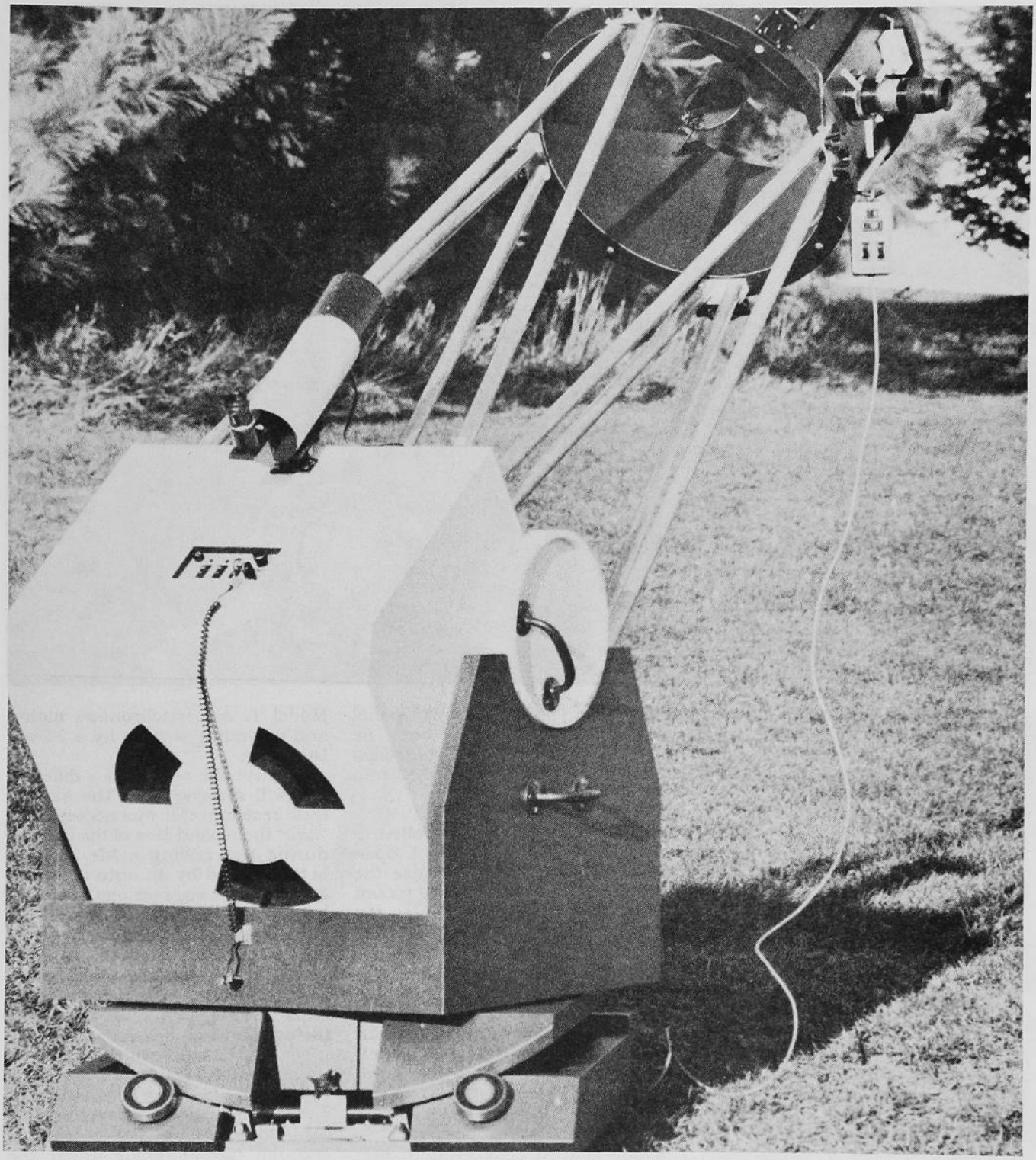
The leads for the coil were run out to the outside of the secondary cage section. I used the spider as one conductor and a strip of adhesive backed copper foil as the other conductor. The copper foil is available from Radio Shack and adheres to one of the legs of the spider.

The first time the system was used, on the foggy night of a Pleiades occultation, it proved its worth. I was able to do a complete set of observations, while a dozen other observers at the same site were either fogged out or missing events while running their hair dryers. While I have noticed no effect on the secondary's figure, some degradation would be better than losing observing time to humidity.

The Hi-Tech Telrad

Because I now had to provide power to the eyepiece section of my telescope, it seemed logical to extend the power to my Telrad. Those of you who have a Telrad know these handy finders are real dew collectors. To remedy that, I enclosed the Telrad in a three-sided box constructed of 3/32-inch aircraft plywood obtained at a hobby store. That created a flat surface close to the eyepiece, so I then added a holder for my Astrocard finder cards by making a three-sided frame from strips of 3/16-inch square basswood topped by a piece of glass. The frame was glued to the side of the Telrad cover and the glass is adhered to the frame with silicon cement.

Before installing this holder to the Telrad, I ran another of the "heat ropes" through the Telrad and around the inside perimeter of the glass for the Astrocard. Power is supplied to these wires through a "battery eliminator" plug in the base of the Telrad. These plugs have isolated contacts that prevent shorts when you connect them hot. The finder card holder is lit by one of

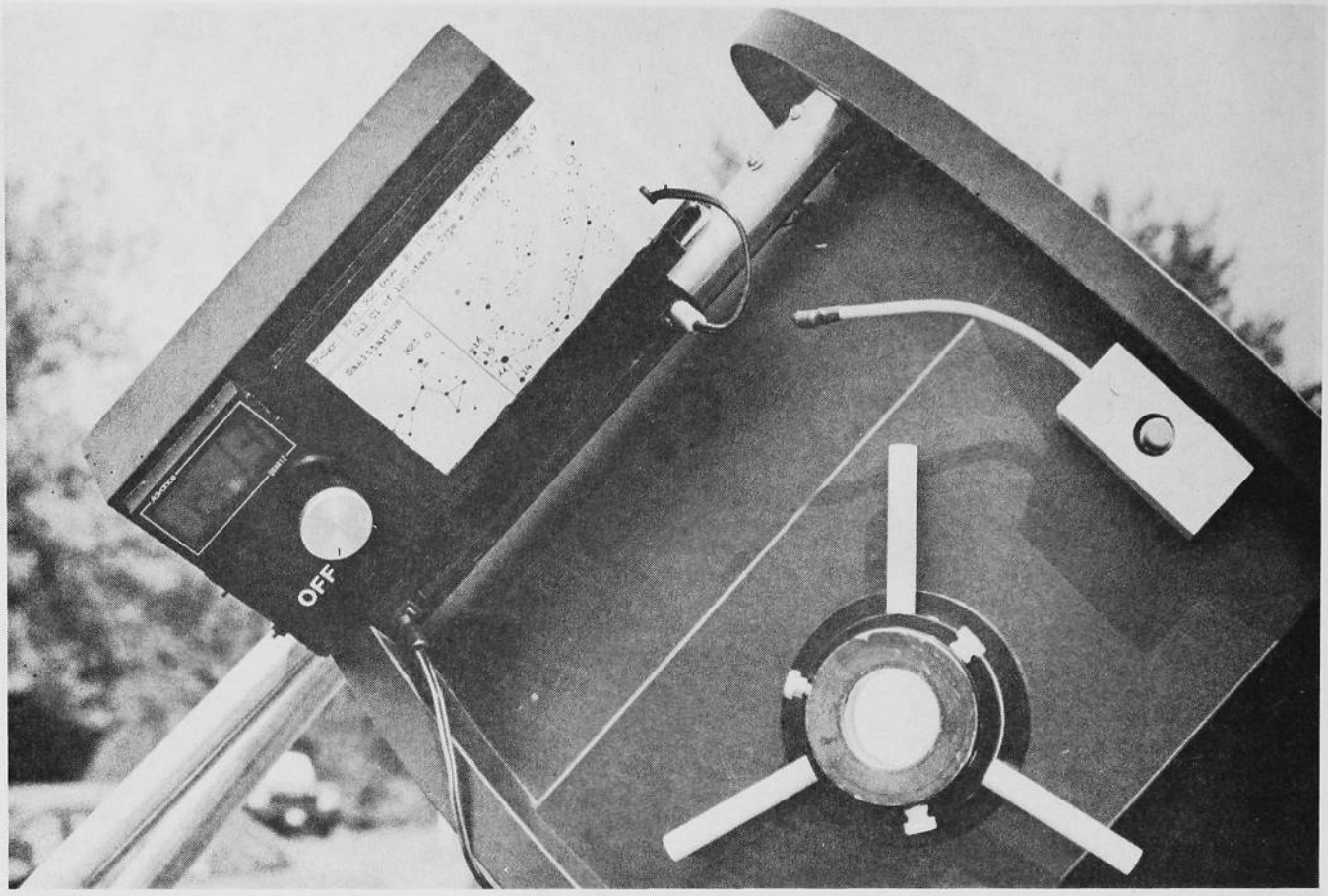


On-board electrical power means putting heat and light where you want them and when you want them. Note control panel.

those spiffy Flexilight LED illuminators obtained from Spectra. I found that the box also provided a convenient place to put a LCD clock. The total cost for the cover was less than $15.

A separate dew chaser for my eyepieces, made from another section of the heating rope inside an elastic band, can also be connected at the Telrad. Power up to the secondary cage is fed by a wire inside one of trusses. I have run similar heating wires around the inside of the objective dew cap and the eyepiece of my other finder. Dew and frost on my optics are now a thing of the past, even in the most extreme conditions.

Once I had begun to "power up" the scope, the solution to my other concerns of cooling and collimation were solved easily. Thanks to a suggestion from Tom Osypowski, I



Finding objects is a crucial function of the observing system—so keeping the finder dew-free is vital to achieving reliable operation in the field.

installed a small computer fan (or "muffin" fan) behind the primary. Because I had already vented the rear of the mirror section, cooling to ambient temperature is accomplished in less than half of the previous time. Once equilibrium is reached, I shut off the fan. The fan produces no detectable vibration in the scope while running, and tube currents are also minimal.

Collimation of my scope using mirror "spots" and a Cheshire eyepiece is a snap. I installed a small bulb inside the mirror box on the back of its front panel. The bulb is out of the light path so it indirectly floods the primary mirror with light and illuminates the hole reinforcement that marks the center of the primary. It also casts sufficient light to illuminate the spot of the secondary. Collimation to very tight tolerances, which is so critical to short f/ratio instruments, is a snap now—even alone in the dark!

I installed switches and indicator LEDs for these additions in a half-inch-thick Plexiglas control panel on the side of the mirror box. The panel is lit by rheostat-controlled LEDs glued into holes drilled into the edges of the Plexiglas.

Putting It on a Poncet

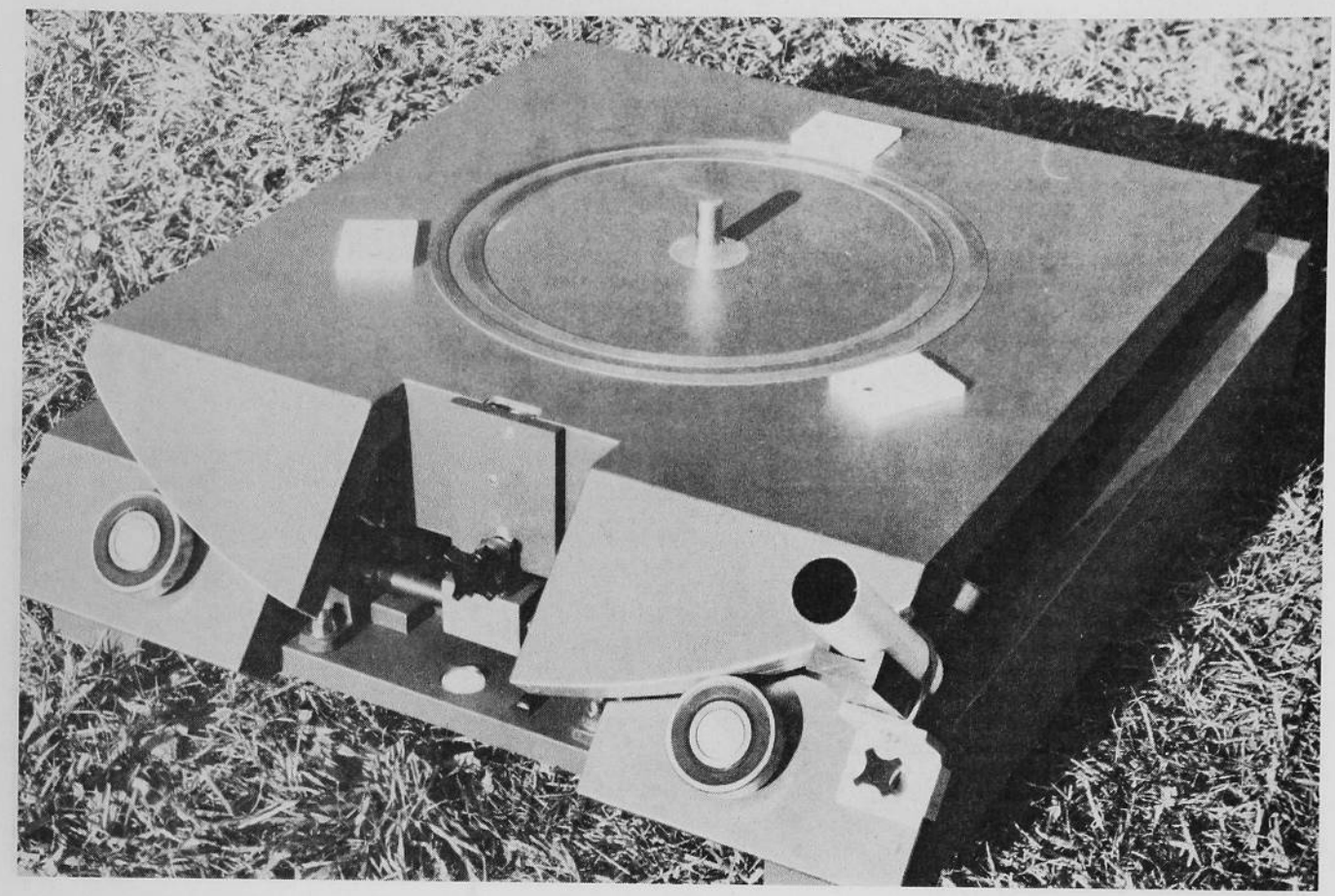
Because my telescope is often in use at our club's frequent open house programs and because the convenience of an equatorial mount in such situations eliminates the task of keeping an object in the field for a succession of observers, I decided to build a Poncet platform for my scope soon after I saw one. The construction of this logical addition to my instrument took far longer than I originally anticipated—mostly because I experimented with several different types of drive arrangements—but the result was well worth the effort.

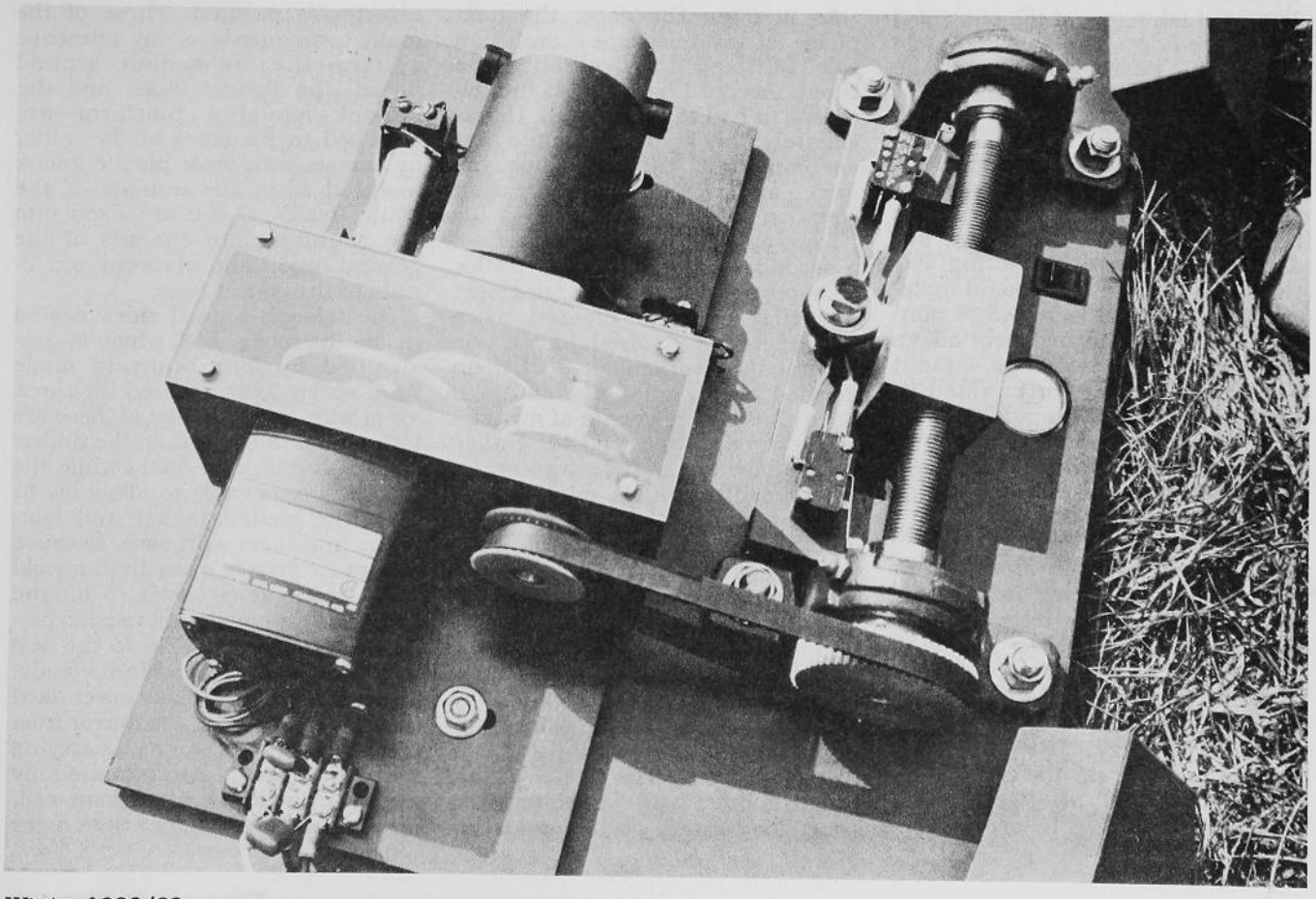
I now have a driven mount that adds only 5.75 inches to the height of my telescope. The key design element was to drive the scope with one motor and rewind through another using a differential—an idea gleaned from Tom Osypowski. The gearbox, which is built with surplus gears, is made entirely of hardwood with hand tools. Tracking rate is accomplished by a Hurst Model T, AC synchronous motor, and rewinding is done by a 24-volt DC motor.

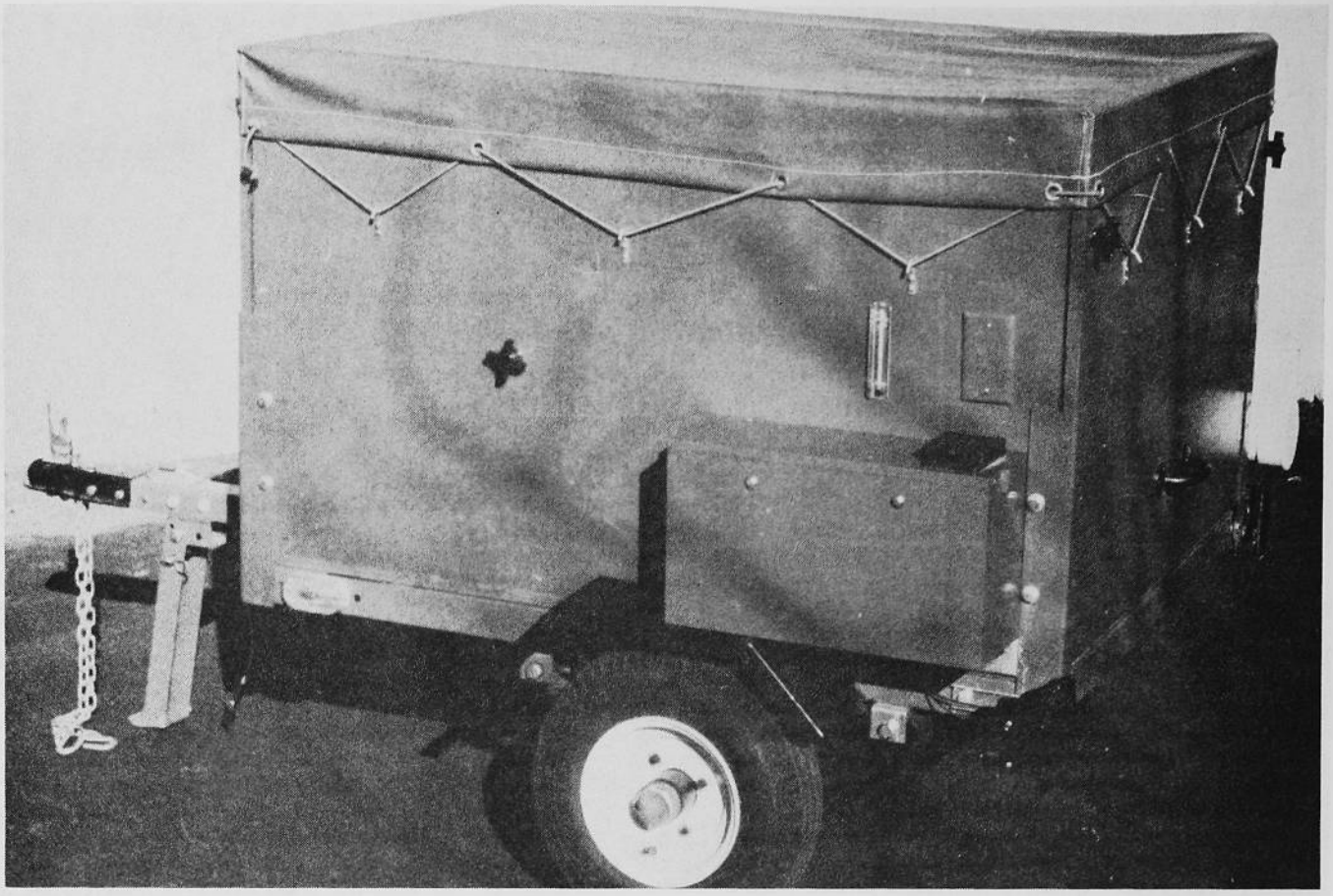
Because the output of a differential will always go to the side of least resistance, it was necessary to "lock" the rewind side of the gearbox during the driving mode. This is accomplished by an auto door lock solenoid that engages one of several holes in an idler gear on the rewind side of the drive. When power is applied to the solenoid, it withdraws a pin from the hole in the gear, and after clearing the gear, trips a microswitch to allow the motor to rewind the lead screw.

The drive tracks continuously for an hour and ten minutes and then rewinds in about ten seconds. Limit switches restrict the travel in both directions. All wiring is carried through two channels under the Formica surface to a central junction area behind the polar bearing block. This protects the three relays and many connections for the drive from damage and moisture. A hand

The Poncet-Pursell platform adds a drive to the lightweight and portable Dobsonian system, an important bit of functionality for any scope.







Putting a telescope at the observing site is, perhaps, the most important part of the observing system. The trailer makes transport very easy.

paddle controls the speed and direction of the drive, as well as rewind functions. Power from the base is carried to the rocker box through brushes contacting two rings of printed circuit board material adhered to the movable platform base. This arrangement allows me to rotate the telescope without winding the power cord around it. The Poncet platform and Dobsonian base are the same size and use the same centering pin arrangement, so I can use either setup as my needs demand.

The Transportation Equation

One of the serious problems in using large telescopes is the time required to load the telescope into your car before traveling to a dark site, as well as the time required to unload it to its storage space afterward—all too often when you're very tired and klutzy. The half hour needed to pack up the scope and then to unload afterward soon became a deterrent to my observing.

As is often the case, the next phase of my telescope's evolution was initiated by necessity: the Honda Accord I had carried the telescope in had to be replaced. Unfortunately, my new car would not accommodate the telescope, so once again the transportation equation had to be balanced.

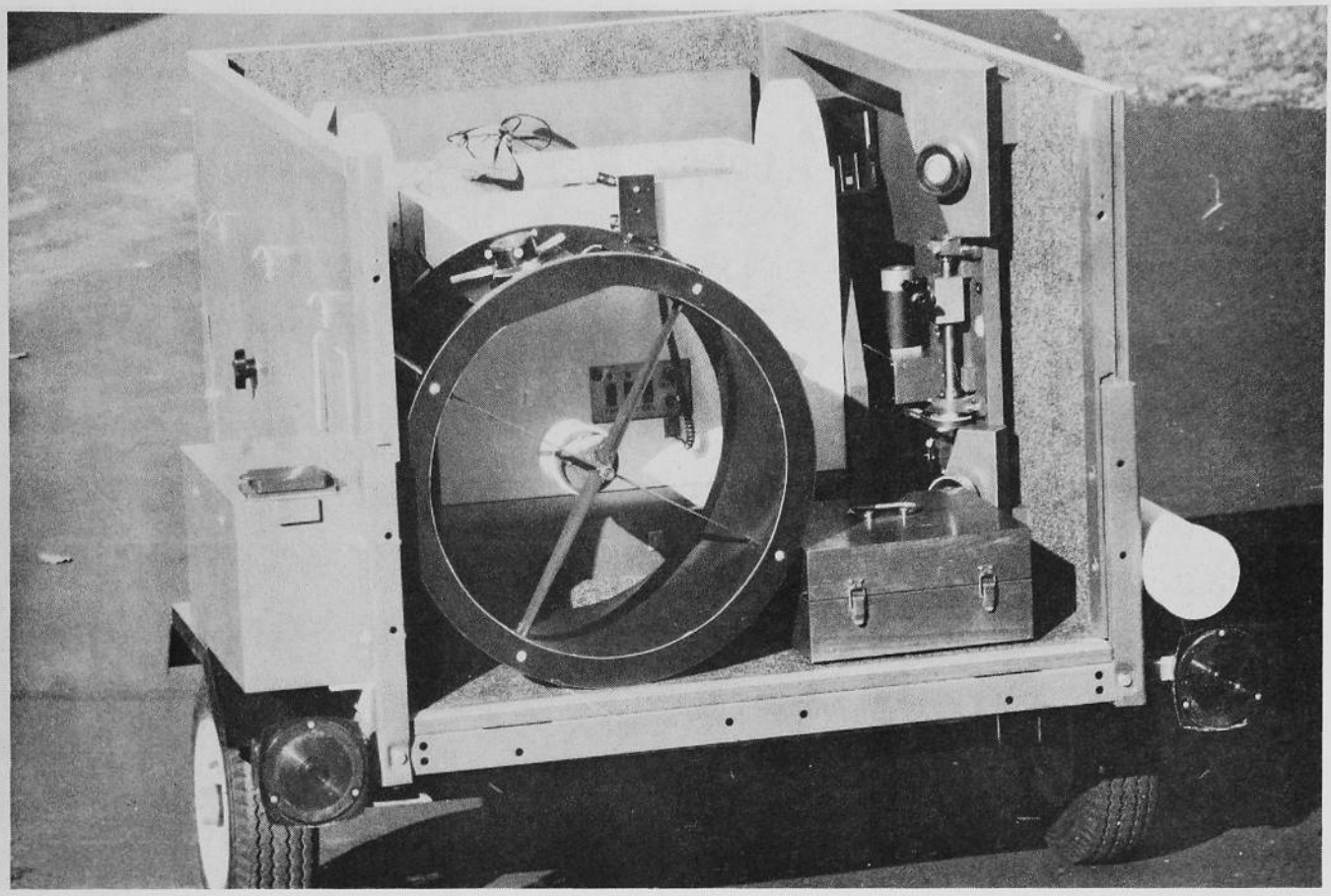
I saw only two alternatives: secure a second vehicle or build a trailer transport system for the telescope. The first solution created more problems than it solved, plus it was financially impractical, so I soon decided on a trailer. I would now have all the components of my telescope in one place, and the trailer would have the added advantage of being readied with a minimum of effort on short notice.

Because my small car could only pull a small trailer, I shopped the local lumber superstores and found a 40-inch by 48-inch trailer frame kit for a little over $125. I made several drawings to make sure I could fit everything in, and it was ideal.

I completed the trailer using 3/4-inch plywood for the floor and 28-inch-high sides. The inside of the trailer is lined with an inexpensive short loop nylon carpet, and the exterior is painted. Three of the main components of my telescope system—the Dobsonian ground board, the Poncet base, and the Poncet movable platform—are attached to the sides of the trailer by screws with large plastic knobs inserted from the outside of the trailer walls. These are fixed into the centering pin threads of the ground board and platform and T-nuts in the Poncet base.

The telescope itself rides nested inside the rocker box, which is constrained by four bumpers made from scrap 2x2s covered on three sides with carpet. Three of these are fastened to the floor from the underside with 3/8-inch bolts, while the fourth is removable to allow me to slide the nested rocker and telescope into them with ease. Because the trailer floor is lower than my old car's trunk, it is easier to lift the heavy mirror box than it used to be.

One major concession to the new mode of transport had to be made, however. Because I have never liked the idea of removing the mirror from a telescope—I'm a card carrying klutz—I originally had mounted my mirror in a Novak nine point cell. The trailer rides rougher than a car



because it has no shock absorbers, so I was concerned about the possibility of a cracked mirror. This mandated a redesign of the mirror cell. I epoxied the back part of the old cell to a 1-inch-thick disk of well-seasoned and sealed plywood and then adhered the mirror to the disk by 3/4-inch silicon pads in a standard eighteen point configuration. Edge support is provided by a sling of webbed nylon belting. The only other change that needed to be made was to the recess mirror collimating springs just slightly to retain the original focal plane location. The nested telescope does not swing in its mount during transport because of its low center of gravity and imbalance when disassembled.

Portable Power

Two utility size, marine deep-cycle batteries supply power to my Poncet platform and telescope. These are held in a Formica-lined box on the outside of the trailer. I need two batteries for my platform, because the drive requires 12 volts to the drive corrector and 24 volts for the rewind motor. The batteries are connected in series with a tap off the positives on both, which supplies the two voltages. I feed the platform power through a grounded extension, using one lead for each voltage and the third pin as a common ground. Also built into the power outlet is a triple-pole, double-throw switch so I can plug my battery charger into the second outlet plug. These batteries run the system for several nights before they need to be recharged and are designed for the type of discharge cycle encountered in my use.

The trusses for my scope are transported in a piece of thin-walled 4-inch PVC tube, which is fixed to the outside of the trailer. The cap at one end is removable and both end caps have a bit of foam rubber glued to the inside to protect the trusses from damage in transit. The tailgate of the trailer also doubles as a standup observing table when I place it carpet-side up on the rear of the trailer. The bolts that hold it in place when in transit serve to constrain its position when I use it as a table for my charts, while my eyepiece case, books, and other observing paraphernalia are stored out of the dew below.

I had a boat cover shop make me a cover for the trailer out of a heavy vinyl fabric, so the trailer is both weatherproof and dust protected. The cover has a nice, snug fit and is held with a shock cord to J-bolts.

When I caught aperture fever in a big way a few years ago, I should have known that a cure for it would require a lifetime of treatment. Thanks to the minds of Mr. Dobson and M. Poncet, I can indulge my desire for "live" views of the faint and fuzzy better than ever, and it's all been without needing the bankroll of Lowell. The trailer has added a further dimension to my observing: convenience. My current observing system satisfies my need to have a large telescope ready to take to a dark site without a lot of fuss. All I have to do is dress for the weather, hitch on the trailer, and go.

Every telescope I've ever owned since my first 3-inch Gilbert reflector has undergone constant improvement. My telescope system will, I'm certain, continue to evolve as my observing needs dictate. Come to think of it—digital setting circles may be the next enhancement.

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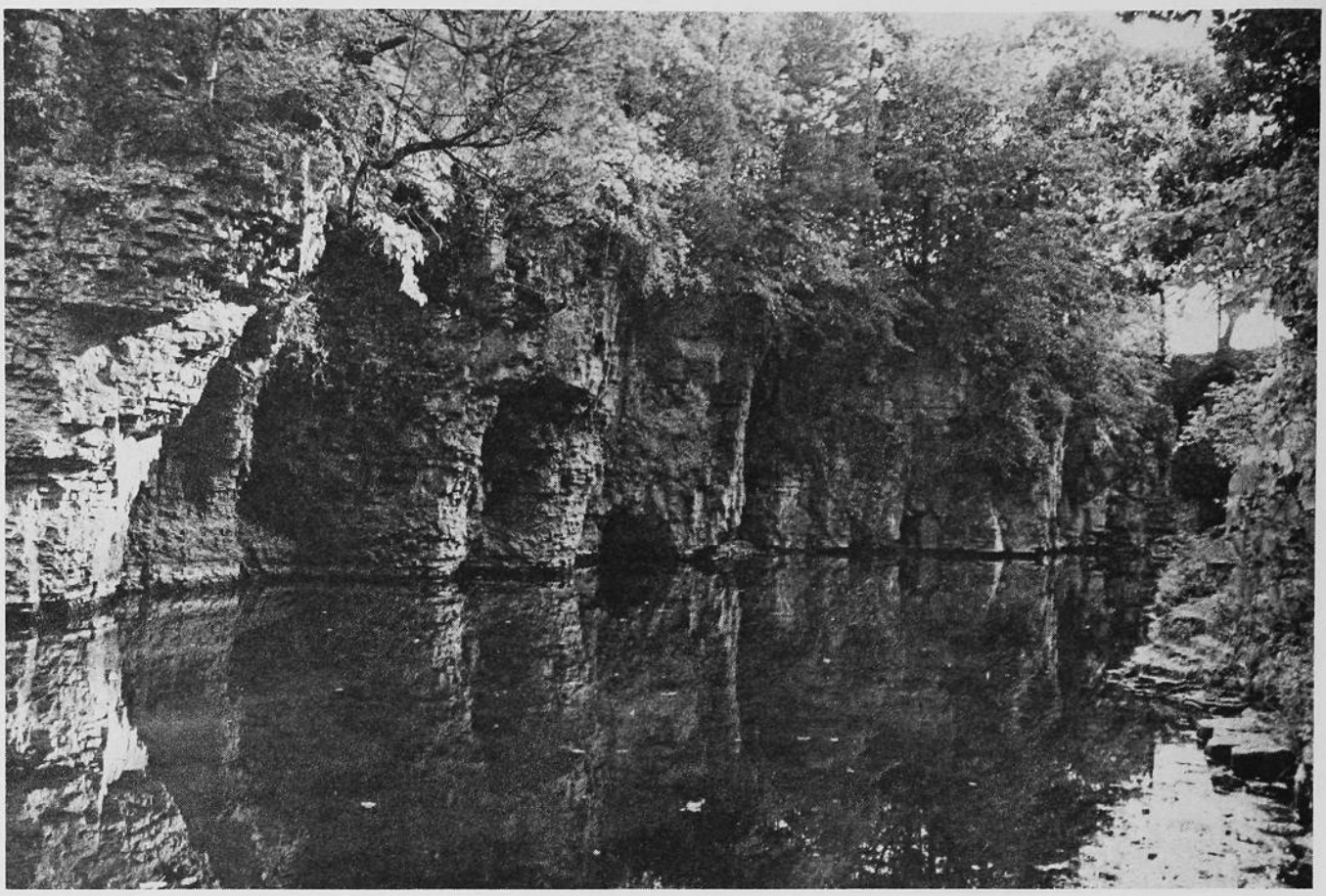


The night sky was hazy with smoke from the Yosemite fires, the air was chill, and my feet were sore, but I still wouldn't give up the night's magic and sleep. As the Earth spun eastward under my feet, Mars spun too in the eyepiece of my 20-inch telescope, and Orion's great nebula drew me back again and again for another look. Space artists Adolf Schaller and Mark Paternostro, down from Chicago, took long turns at the eyepiece, until they had seen the nebula thoroughly—with artists' eyes for subtlty and and artists' memories for detail.

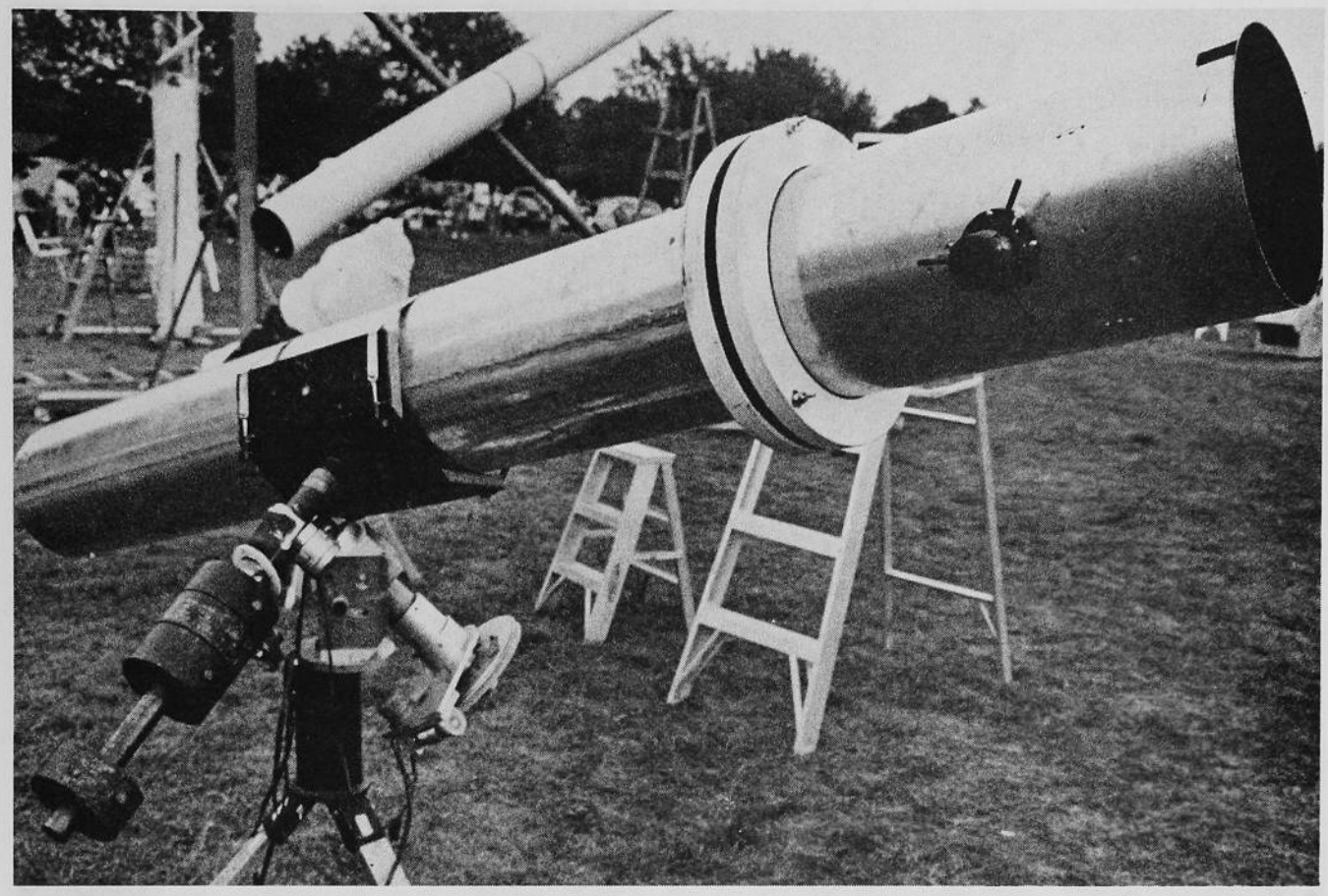
Looking through telescope after telescope that night was fascinating. In the course of twenty minutes, for example, I viewed Mars through a 7-inch apochromatic refractor, a 10-inch Tri-schiefspiegler, and a 20-inch Dobsonian reflector. All three instruments gave a good view of Mars; all three were diffraction limited; and the large-aperture telescope in each comparison gave a more detailed view than the smaller one—exactly as should happen! The refractor gave the cleanest images, to be sure, but the reflectors *showed more* on the planet.

This year, for the first time, I took a few hours to look around Camp Shaw-waw-nas-see, where Astrofest is held. The Rock Creek gorge is beautiful and fossil-filled, and there are nice trails to walk along, cool after a day in the sun. Ele and I brought our Coleman stove and warmed our beans over the campfire this year—a nice escape from the usual "line up for the cafeteria" ratrace.

In the pages that follow, I touch on just a few highlights of the best Astrofest ever.

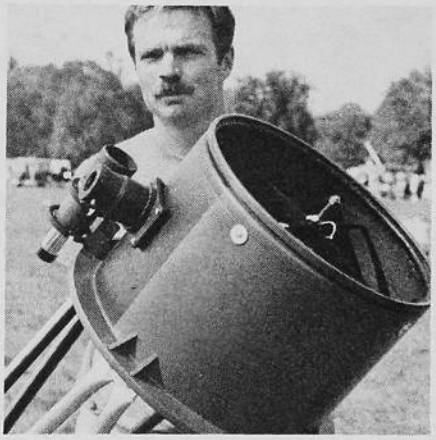
—RLB

ASTR



a variety of clever designs

Carl Buzzard designed a wooden rotatable upper end for his 10-inch Newtonian. The upper end carries a wood flange trapped between channeled rings attached to the lower tube. Ralph Heiden showed a small Dobsonian binocular with precisely matched mirrors—matched by grinding and polishing both on the same tool. Jeff Inman's 13-inch Dob uses a fiber-drum upper end that flips over to store in the mirror box.



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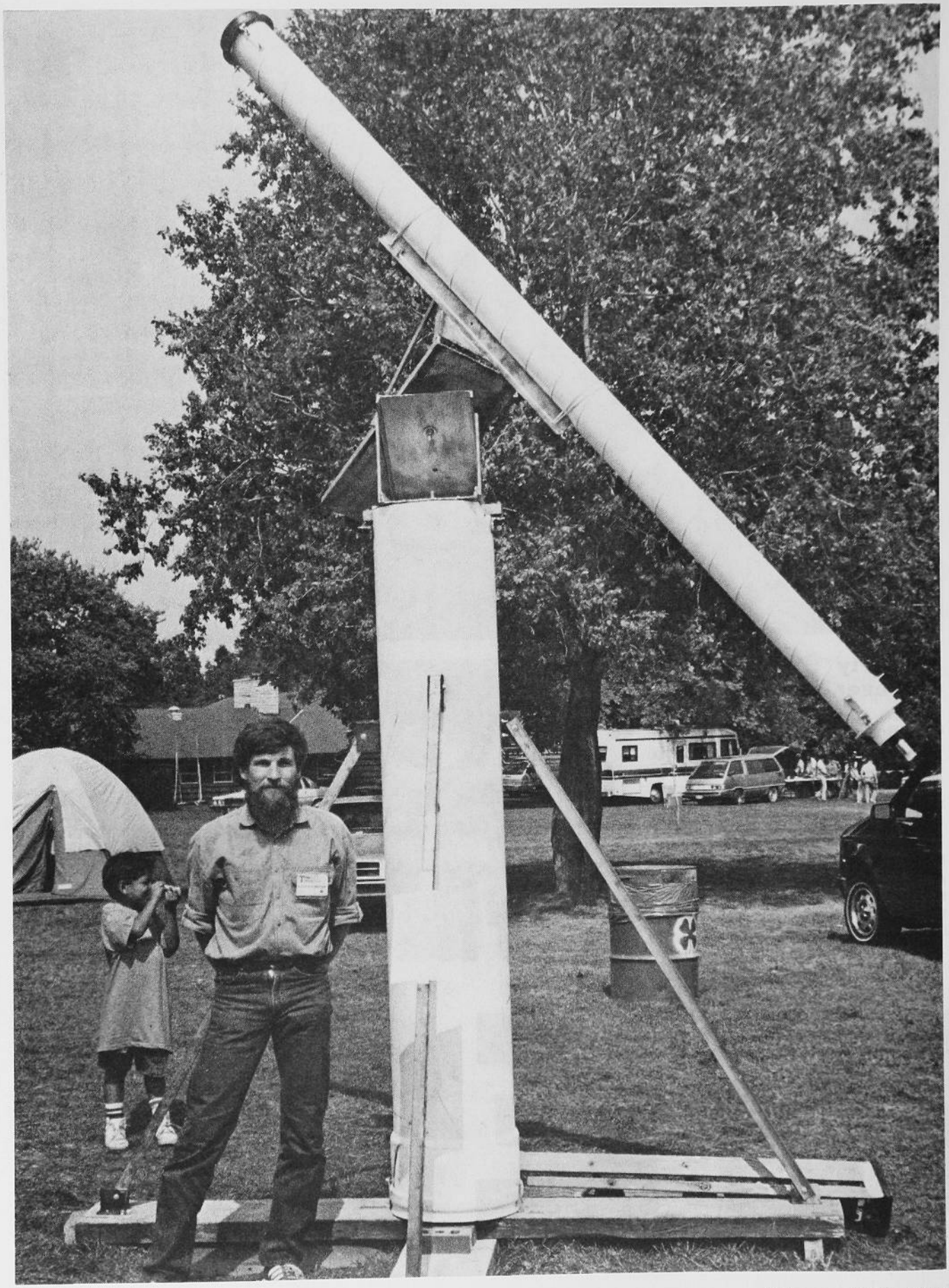
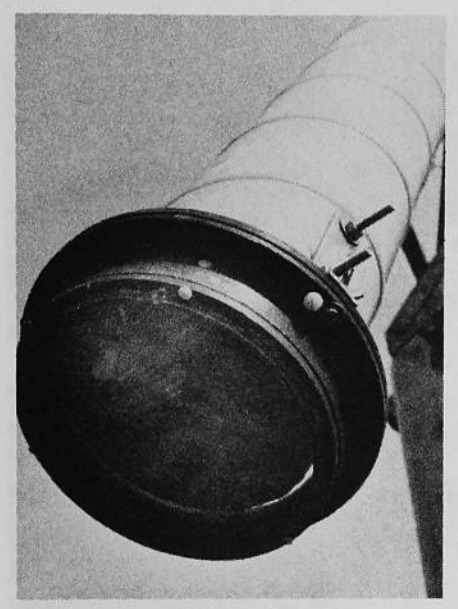
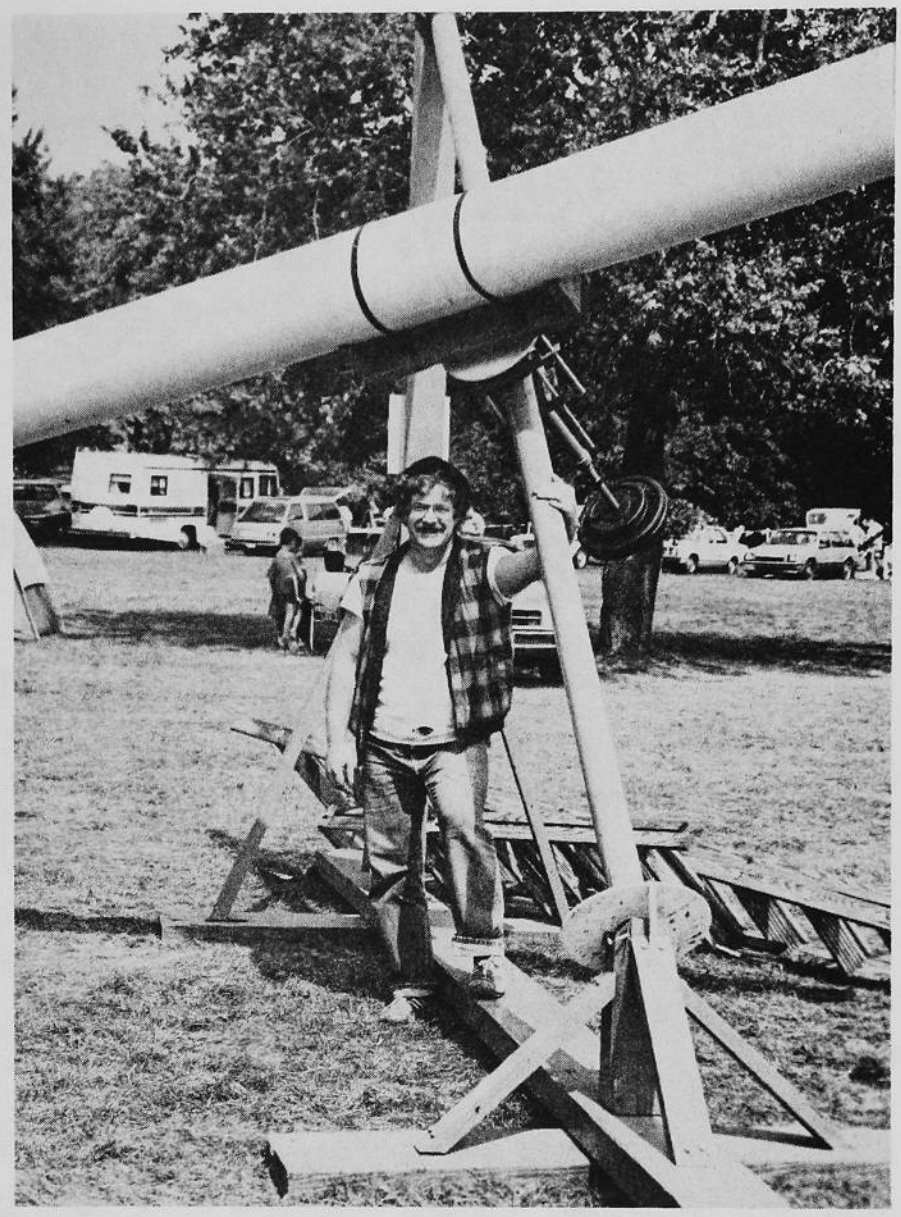


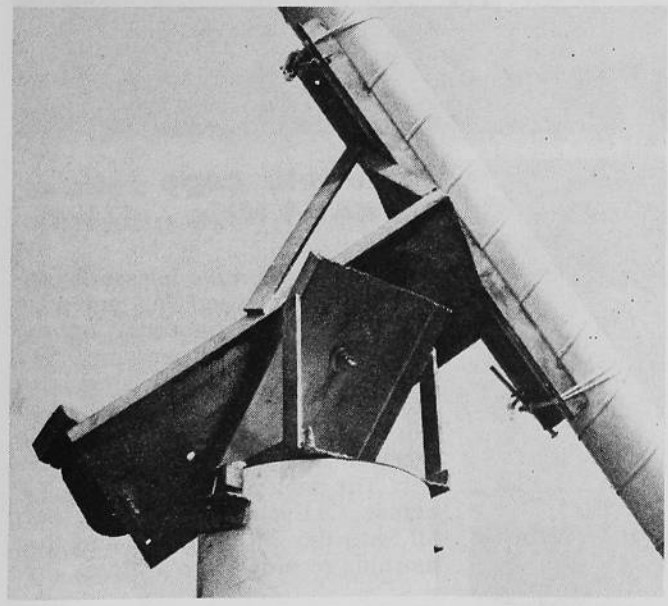
Telescope Making #35

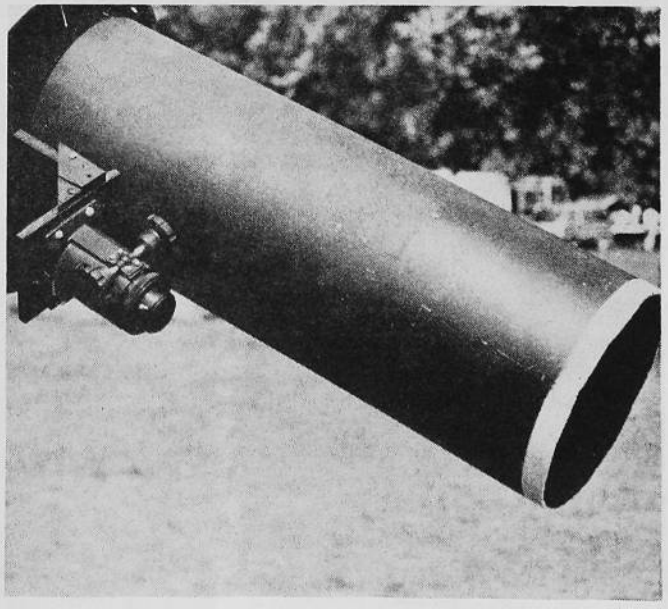


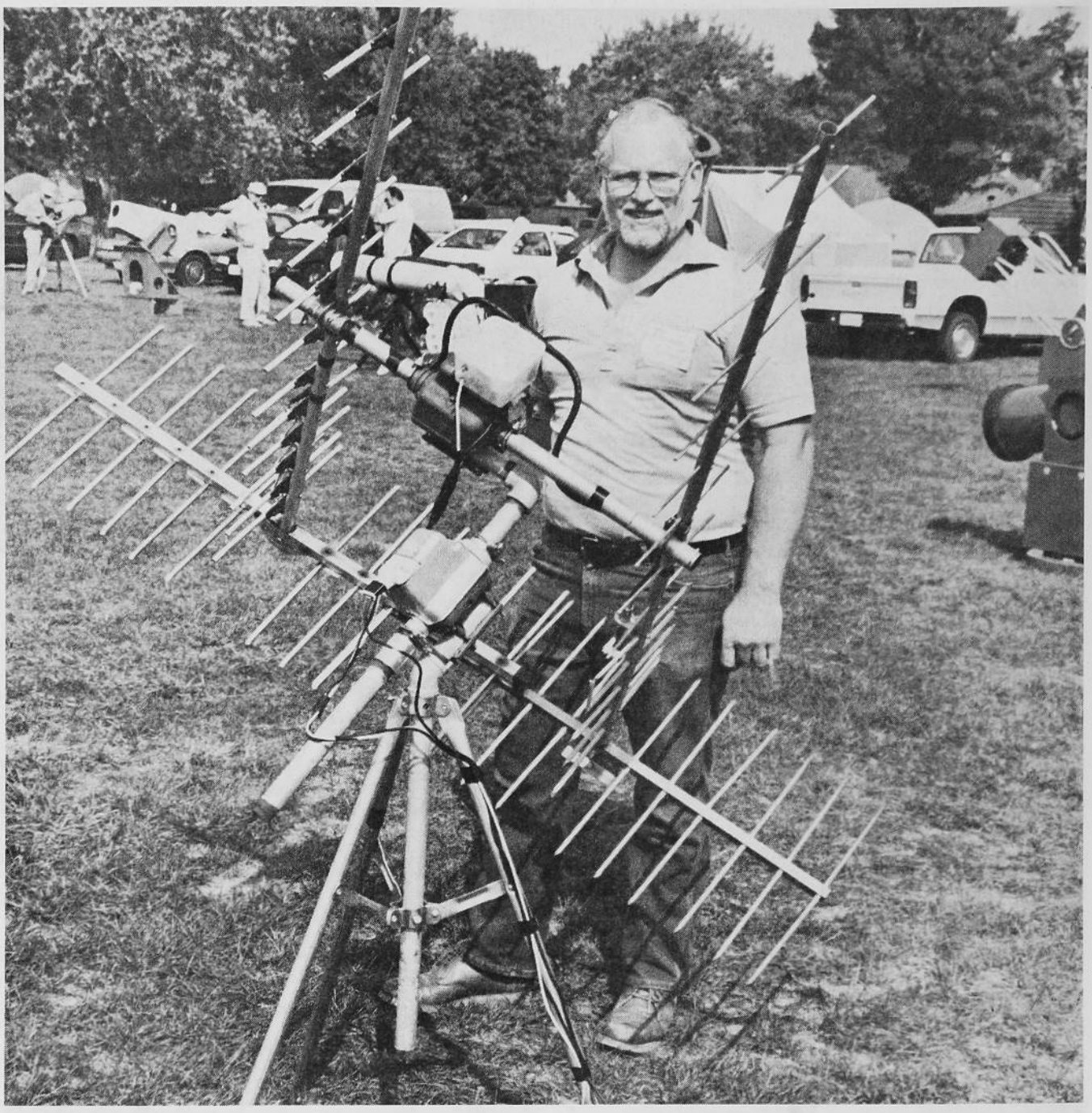


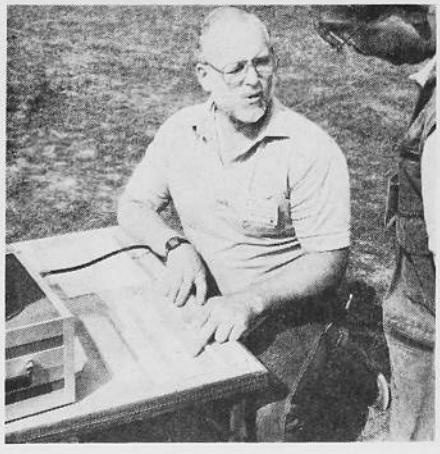
two tall telescopes from iowa

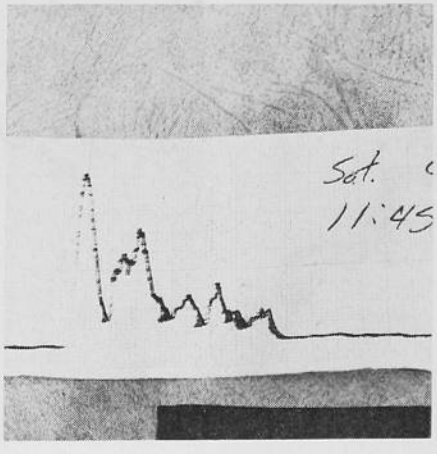
Andrew Sorenson of Jefferson, Iowa showed a marvelous 6-inch f/21 Littrow refractor on an enormous home-built mounting. The Littrow lens is a very simple achromat in which -R1=R2=R3=0.419F, and R4 is flat. Because of the long focal ratio, the lens was very nearly color-free. Mounted in a fibreglas cell on an irrigation-pipe tube, the telescope performed quite well. Beside the refractor, Jim Axness of Perry displayed 6-inch f/27.3 Herschelian reflector on a truly monumental cross-axis mounting. The tube beside the focuser warm air from the observer's body out from entering path of the incoming light.









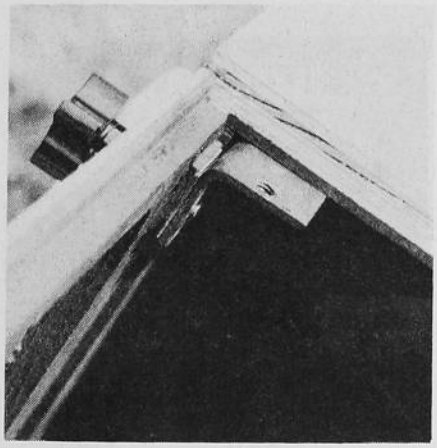


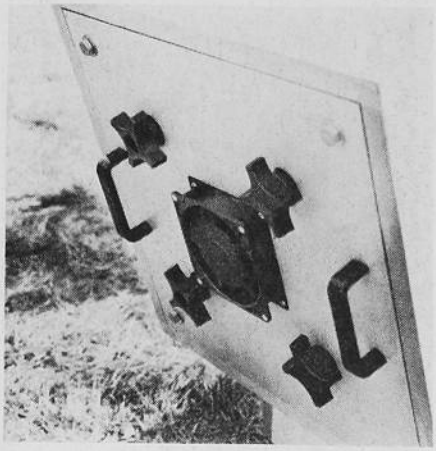
radio telescope for 441.1 MHz

Don Cathcart's radio telescope consisted of two phased Yagi antennas with 17dB gain; mounted on the antenna is a 15dB preamp. "My main objective was not to spend any money," said Cathcart, but he had put $10 into the rebuilt Motorola receiver and $5 into a chart recorder. The main beam is about 30° across. Cathcart observed the Sun all Saturday at Astrofest, and that morning recorded a solar flare.

a slick 12-inch portable dobsonian

John Asztalos showed a neat 12-inch f/4.8 Dobsonian with a break-away center tube section, a built-in finder telescope, gel-cell electric power for heating the finder and focuser, fan-forced tube ventilation, and an orthagonal mirror cell, The tube walls are made from 1/8-inch plywood reinforced at the edges; four knobs secure each of the center panels to the upper and lower ends. The telescope weighs 70 pounds.





Telescope Making at ALCON '88

A Pictorial Report

The League meeting in Council Bluffs held some pleasant surprises for this telescope maker.

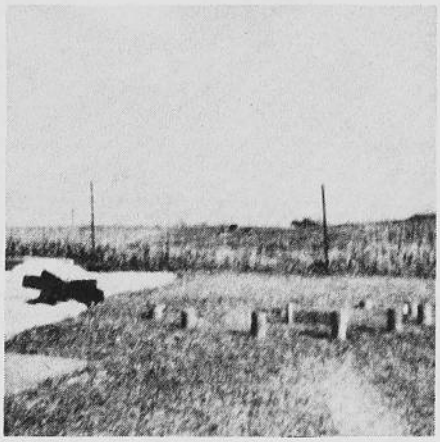
I was delighted by Phil and Margaret Heflin's delightful rotating observatory. Phil built it around 10-foot playground merry-go-round, as an observatory for Margaret. Atop the turntable sits metal garden shed with a removable shutter; Margaret observes with a binocular fashioned from surplus apogee scopes. Shades of Leslie Peltier!

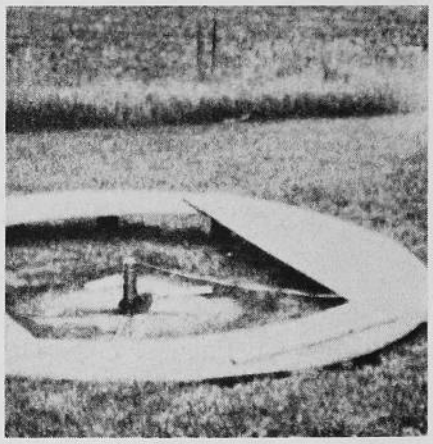
At the swap meet I saw a Schmidt camera made several decades ago by August Wedt, asking $400. From the negatives I saw, this 8-inch f/1 instrument never gave good images —but it's s a real beauty.

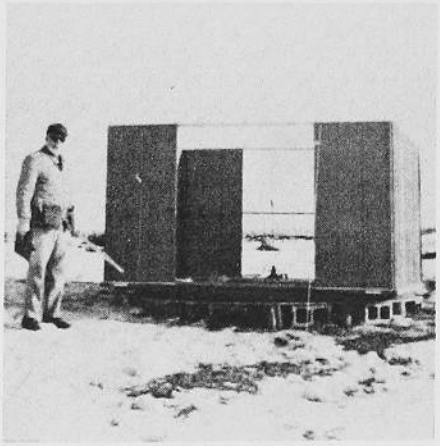
John Dobson wowed the crowd by making a mirror in a day, with Dick Suiter's Foucault program reducing zonal readings.

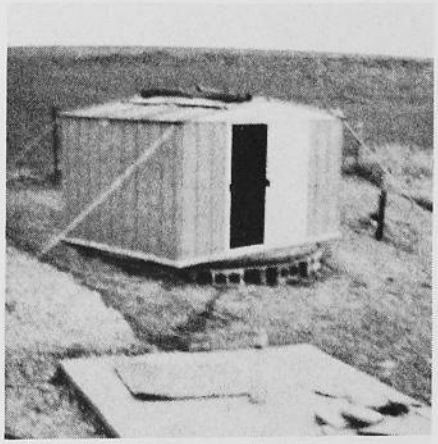
An outstanding amateur project was restorating of a 12-inch f/15 Clark refractor by members of the Southeastern Iowa Astronomy Club. We'll bring you the full story in a future issue of *Telescope Making*.

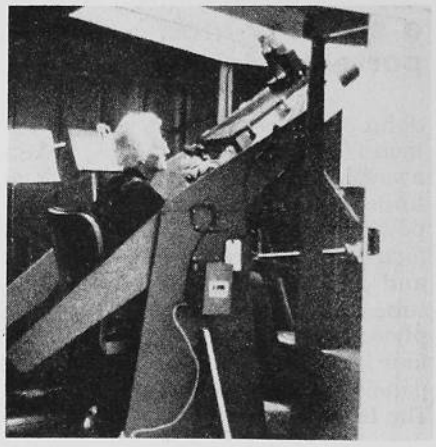
—RLB

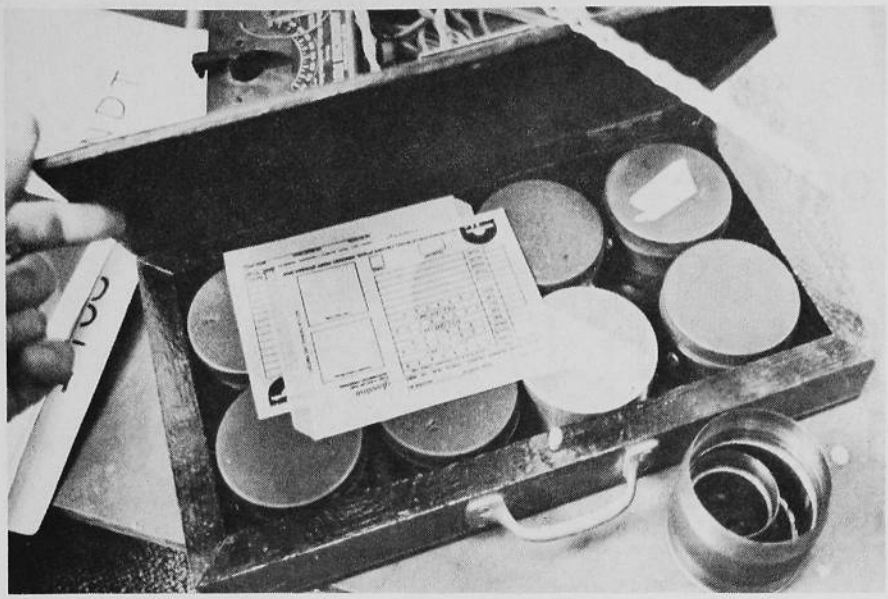


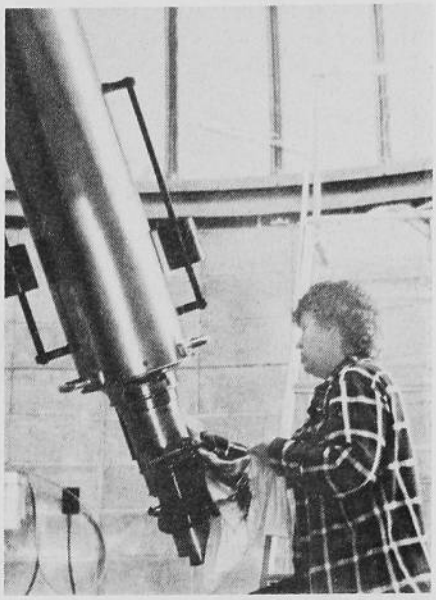


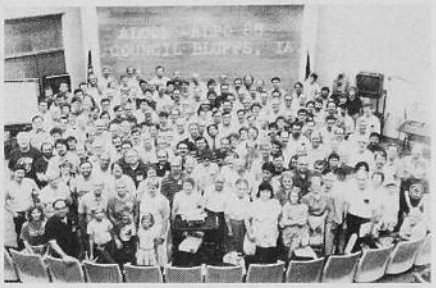


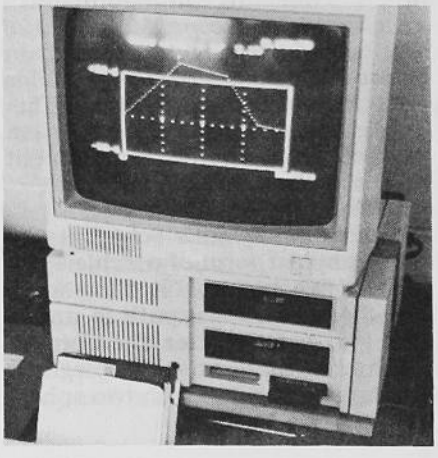












Notes on the Construction of a 10-inch f/20 Buchroeder Trischiefspiegler

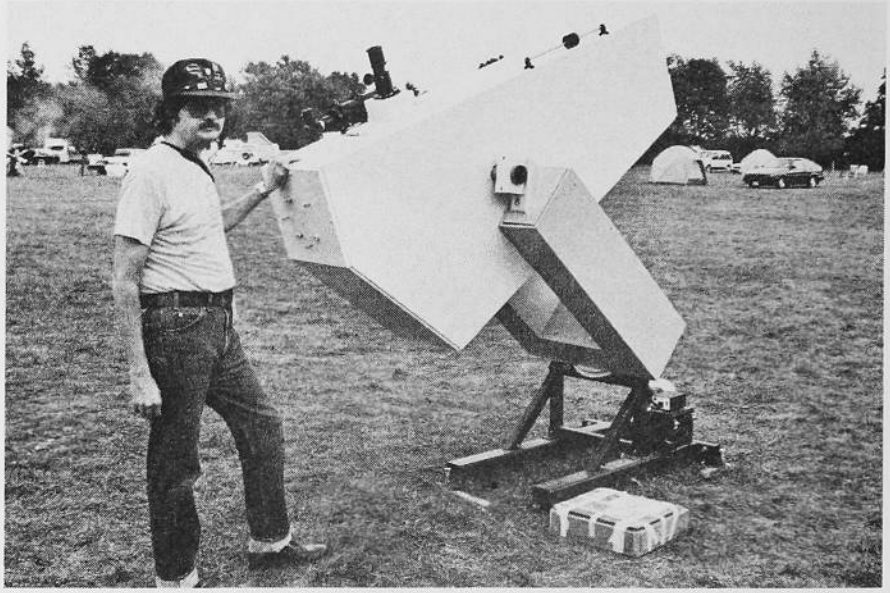
Discouraged by the high costs of refractors but intrigued and attracted by the enthusiastic claims of the owners and makers of schiefspieglers, I decided to make a high-performance unobstructed reflector for myself. For quite a while I had been curious to see what kind of performance I would get from an unobstructed telescope. I had experimented with a 6.5-inch aperture off-axis mask on my 17.5-inch Newtonian, with indifferent results on the planets, and had concluded that a large Newtonian with an off-axis mask was not the most efficient way to obtain a good-sized unobstructed aperture of high quality. The articles by Richard Wessling and Steven Johnston on their 12.5-inch trischiefspieglers in *Telescope Making #28* really caught my interest, and I decided to begin with a 10-inch f/20 Buchroeder trischiefspiegler.

The fabrication of the optics went smoothly, and the construction of the tube was easier than I had anticipated. This was in large part due to Wessling and Johnston's articles in *Telescope Making #28* and to A. L. Woods' two articles in *Telescope Making #16*. To these TMs I owe a great debt of gratitude. This article will deal with things I have learned that should supplement their articles.

Schiefspiegler Optics

Kutter Anastigmatic Schiefspiegler

The simplest form of a schiefspiegler has two mirrors, tilted in such a way that the optical path is unobstructed. Anton Kutter, the German designer of the first schiefspieglers, began his designing with two spherical mirrors to avoid hard-to-make aspheric surfaces. He also chose to make these mirrors of the some radius to facilitate fabrication. Then he chose long radii with a low secondary magnification. Finally Kutter found that by properly tilting the secondary mirror, he could minimize aberrations. He found there were three basic positions that the secondary could be tilted in. One suffered from both residual coma and astigmatism, another corrected coma but left astigmatism uncorrected, and the third position corrected astigmatism but not the coma.

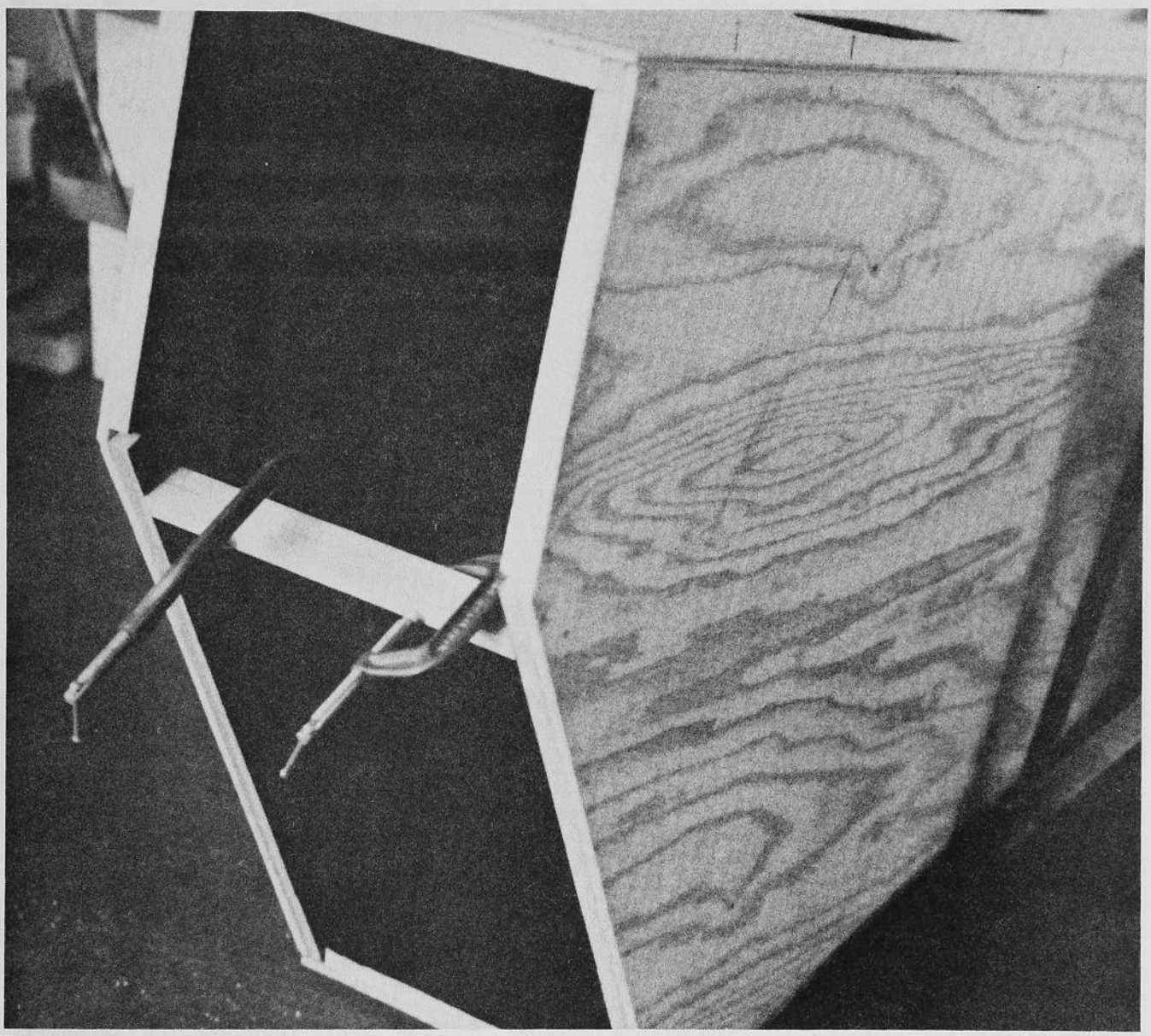


Jesse Carroll of the Chicago Astronomical Society stands beside the "schief" during the 1988 Astrofest. The scope gave fine images.

Kutter chose the third, anastigmatic design and lengthened the radii to the point that the coma was reduced to below the size of the Airy disk. For a 4.25-aperture the system had to be f/26, and a 6-inch aperture would have to be f/29 to yield a workable anastigmatic system. Thus, a 4.25-inch is the largest practical aperture for this design.

Kutter Catadioptric Schiefspiegler

For larger apertures Kutter chose a "golden mean" tilt for the secondary, a tilt between the anastigmatic and the coma-free positions. To compensate for the residual coma and astigmatism, he introduced a tilted, weak plano-convex or cylindrical lens positioned between the secondary mirror and the focus. This lens corrected the residual aberrations



This rear-end view shows the tube under construction. The primary-mirror cell bolts onto the back by means of threaded inserts installed in the 3/4-by-3/4-inch framework. The lower end panel is removable for access to the primary and tertiary mirrors, and for cleaning and aligning the tertiary.

yet introduced almost no chromatic aberration. The chromatic aberration could be further reduced by making the lens slightly wedged or decentering it in the light path. This design also requires that the primary be an ellipsoid of 55 to 60 percent parabolic correction. The final system worked out to f/20.

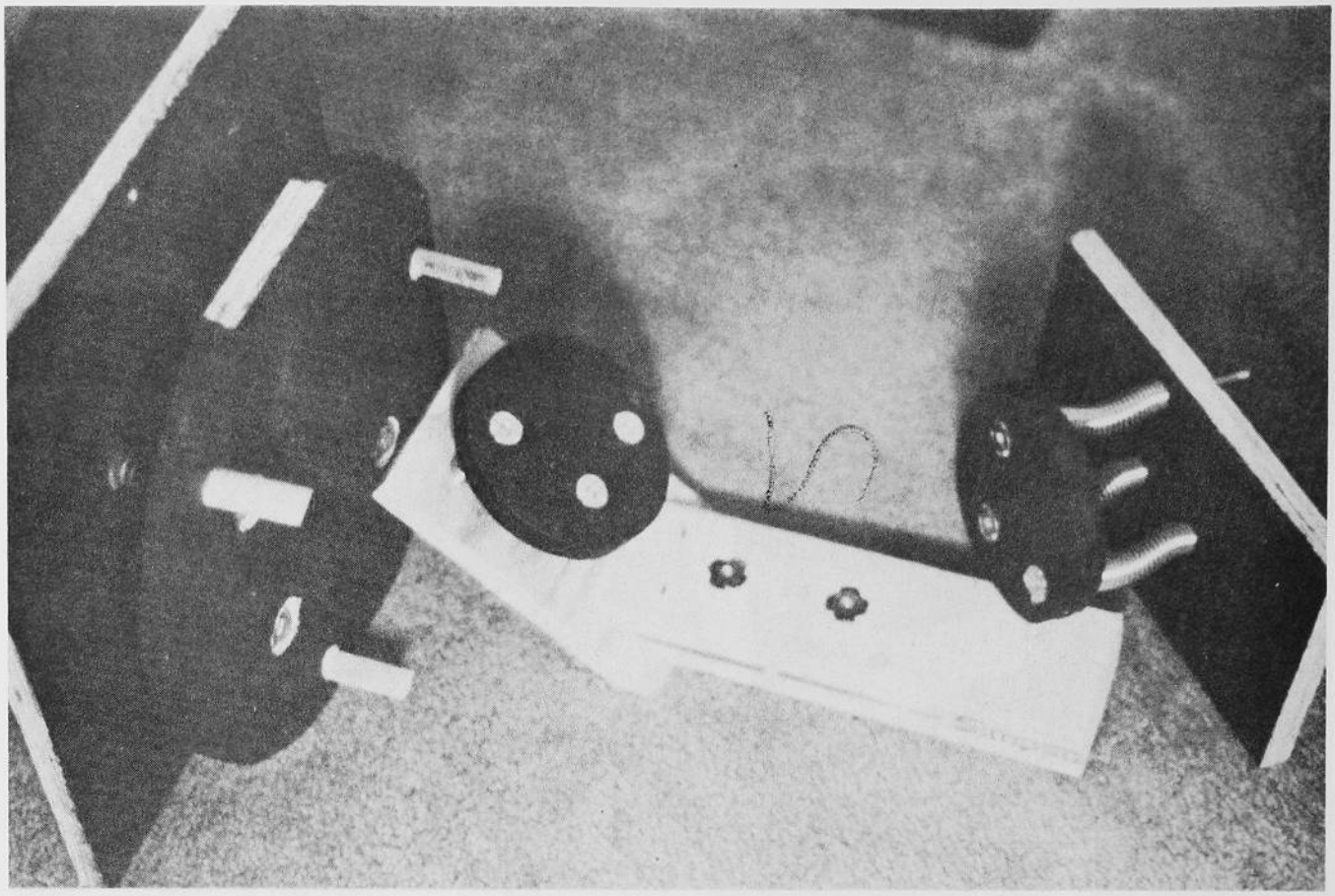
Kutter Trischiefspiegler Later Kutter replaced the correcting lens with a third spherical mirror with a very long radius. This resulted in a more compact system that was absolutely color free. This was designed for f/14.7.

Other TCT Designs Other tilted component telescopes have been designed; the most noteworthy are Arthur Leonard's Yolo and Solano designs. These designs seem to work well, but the Yolo requires a warped mirror, which is difficult to make warped or inherently instable if a spherical mirror is mechanically warped.

Leonard's Solano TCT with a hyperbolic primary and spherical secondary and tertiary mirrors looks promising. It can be made in a variety of f/ratios. At the present time, not enough of these have been made to determine their workability. They are supposedly more sensitive to alignment than the Buchroeder trischiefspiegler.

Buchroeder Trischiefspiegler In December 1964 Dr. Richard Buchroeder published a modified trischiefspiegler design using three mirrors of equal radius to facilitate construction. This system works but has a relatively large amount of anamorphic distortion and image tilt.

Buchroeder later redesigned his trischiefspiegler so the primary and secondary had the same radius, but the tertiary had a much longer radius. This design is an improvement over the Kutter designs and yields extremely high quality images with minimal field tilt (9 degrees) and anamorphic distortion



The three mirror mounts for the "schief," shown here before installation, before locking screws were added to the mounts to prevent loss of collimation during transport. The mirrors were glued into the cells with silicone adhesive; dowel pegs are used only for the relatively heavy primary mirror.

(1 percent). It has proven to be quite workable in actual use. This design is described in *Telescope Making #28*, pages 32-51.

Optical Fabrication

Tertiary Mirror I followed Richard Wessling's advice in *Telescope Making #28* and found it extremely helpful. I used a dial indicator spherometer 4 inches in diameter accurate to ±0.00005 inches and with practice got to within 4 feet of the desired radius. This difference can be polished out or a return to a 15-micron abrasive for a few minutes can remedy it quite easily. At this stage you'll want to flash polish the tertiary as soon as possible and make a radius check with the Foucault test. Only a few minutes of polishing is needed.

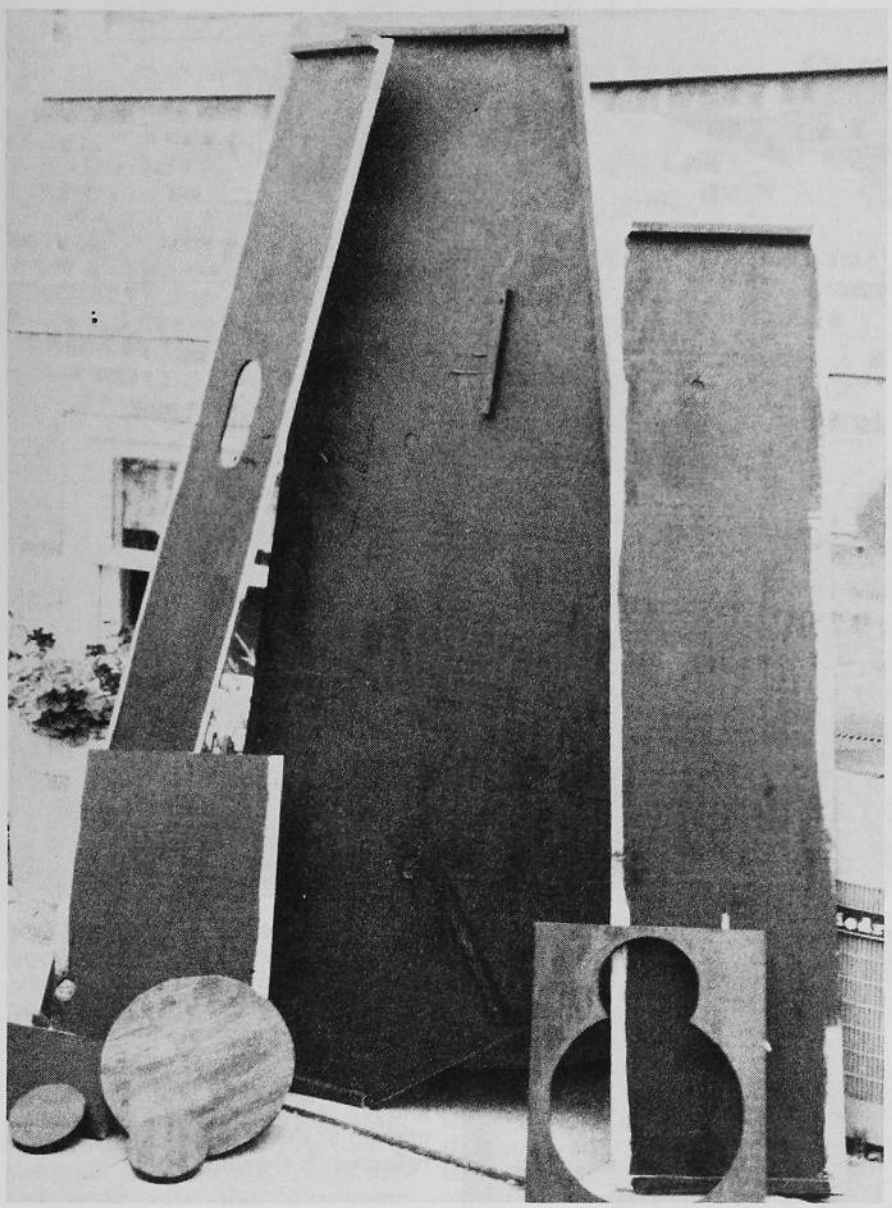
I found that a large flashlight was most helpful in catching the reflection from the mirror. The larger the light source, the better. With practice, once the mirror stand was adjusted, I could walk backwards at full speed with the flashlight by my temple to the approximate focus at which point I used an 11x80 finder on a tripod to catch the reflection. Then I switched light sources for a tiny "Mini Mag" light bulb. This is fine for a bright "pinhole" source at the extreme distance involved. I used a hand-held knife edge in front of the telescope and moved the scope until I reached focus.

The greatest challenge I had was to get a smooth surface. Roughness really stands out on long f/ratios—here f/167. Excellent lap contact is a must. If you have a turntable, use it: it seems to be easier to generate a smooth surface polishing on a rotating turntable. I did this for my third set of mirrors and it was a real time-saver.

Be prepared for a challenge: not only are such long focus mirrors touchy (they will change 6 inches in radius while cooling when they come off the lap), but setting up the test can be quite tedious until you get the knack of it. When the mirror looks good under the test, you can be confident you have a very accurate mirror because the Foucault test for a sphere is extremely sensitive at such a long f/ratio. Completing a tricky piece like a tertiary mirror is very gratifying.

Secondary Mirror This was easy compared to the tertiary. The interference test, described quite well by Richard Wessling, is very convenient. Grinding the secondary against the primary is the best way to keep the radii close. I used a full-sized polishing lap at all times. Quite a few rings of radius differences can be polished out quickly. I avoided the modified laps mentioned by Wessling and Johnston. It may have taken a bit longer to reach the radius, but the radius was reached in a fairly spherical manner and required less figuring.

One problem with the interference test is that it doesn't show roughness as clearly as the Foucault test; so when the lap and figuring techniques used on the tertiary worked well, I used the same pitch and technique for the secondary. Roughness shows up in the interference test as a roughness or indistinctness of the edges of the fringes. This becomes more sensitive with only



The tube parts are shown painted black and ready for assembly. Note that the 3/4-by-3/4 framework is attached to the large side panels first. Then the long, thin panels are attached with glue and screws. The two pieces of 3/4-by-3/4 material on the inside of the large panels are for attaching the baffles. The tube box is made of 3/8-inch plywood.

one or two bands across the mirror.

Test the secondary against the polished spherical primary as soon as you can get a flash polish in it. This will let you know whether you need to lengthen or reduce the radius, which you can do as you polish the secondary. Also, monitor the radius periodically during polishing to determine whether to polish with the mirror on the top or bottom.

Primary Mirror Little needs to be said on this account. Begin the 55 percent parabolic correction from a perfect sphere. You should have this to test the secondary. You must start with an extremely smooth surface because the correction goes in quickly and there is little chance to correct irregularities while polishing in the correction.

Tube Fabrication

This part of the work was much easier than I imagined it would be. There is nothing inherently difficult in making a trischiefspiegler tube. It is more complex than a square Newtonian tube because it requires three mirror mounts, but the construction is simple, at least the way I made mine.

First I drew out the optical system full scale and drew a box around it, allowing 2 inches on each side of the mirrors. To draw the angles, I ascertained their tangents and drew the appropriate right triangles. This yields a drawing of high precision. To transfer this oddly shaped figure to the 3/8-inch plywood, I put the plans over the wood and hammered nails at each corner, and then I removed the drawing and snapped chalk lines between the nails.

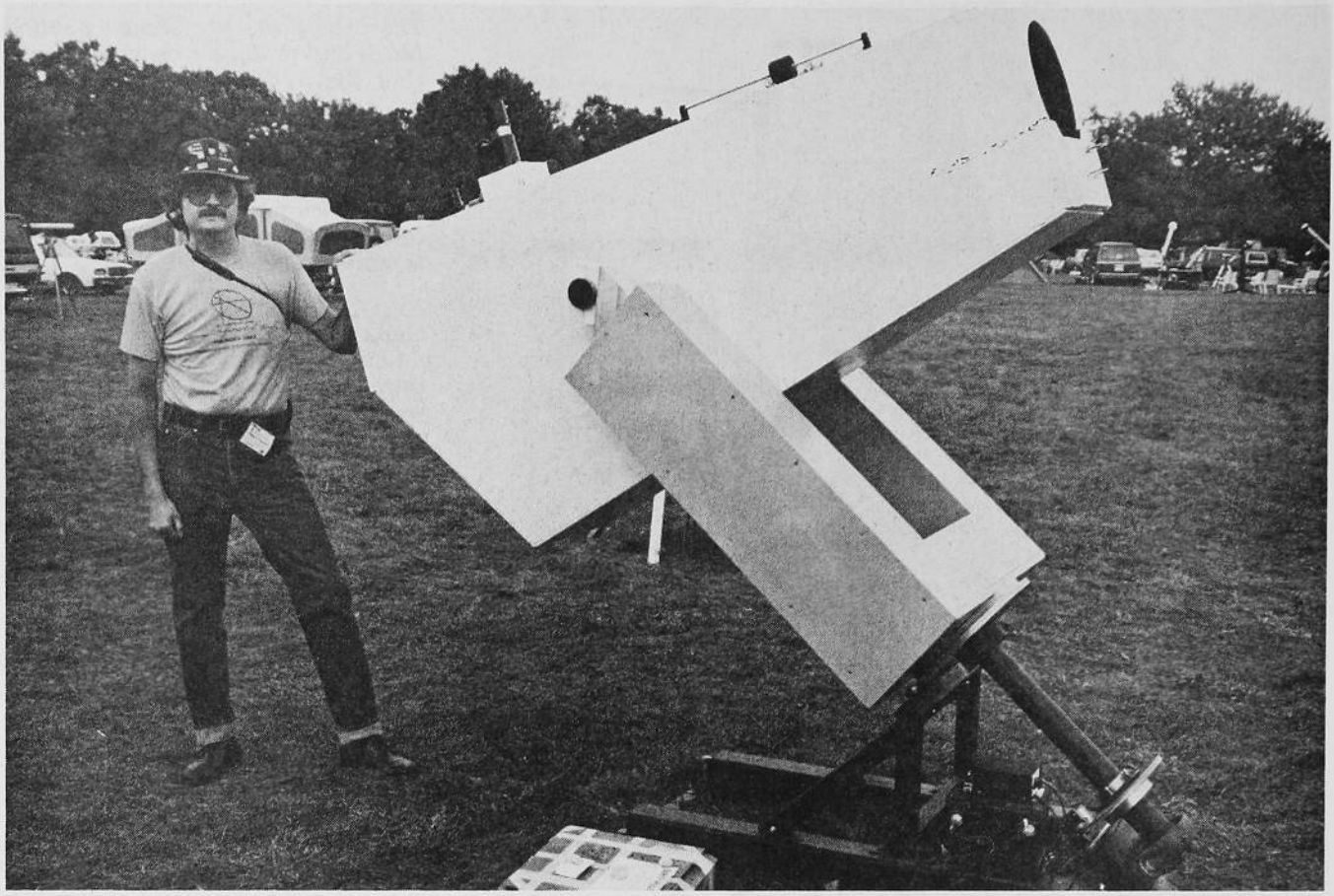
I cut both sides at once to insure they were the same size. The sides were 14 inches wide and the lengths were determined from the drawing. I used 3/4-inch by 3/4-inch stair baluster lumber for an inner framework, glued and screwed into place. This provided a tube of great rigidity. The empty tube weighs about 60 pounds.

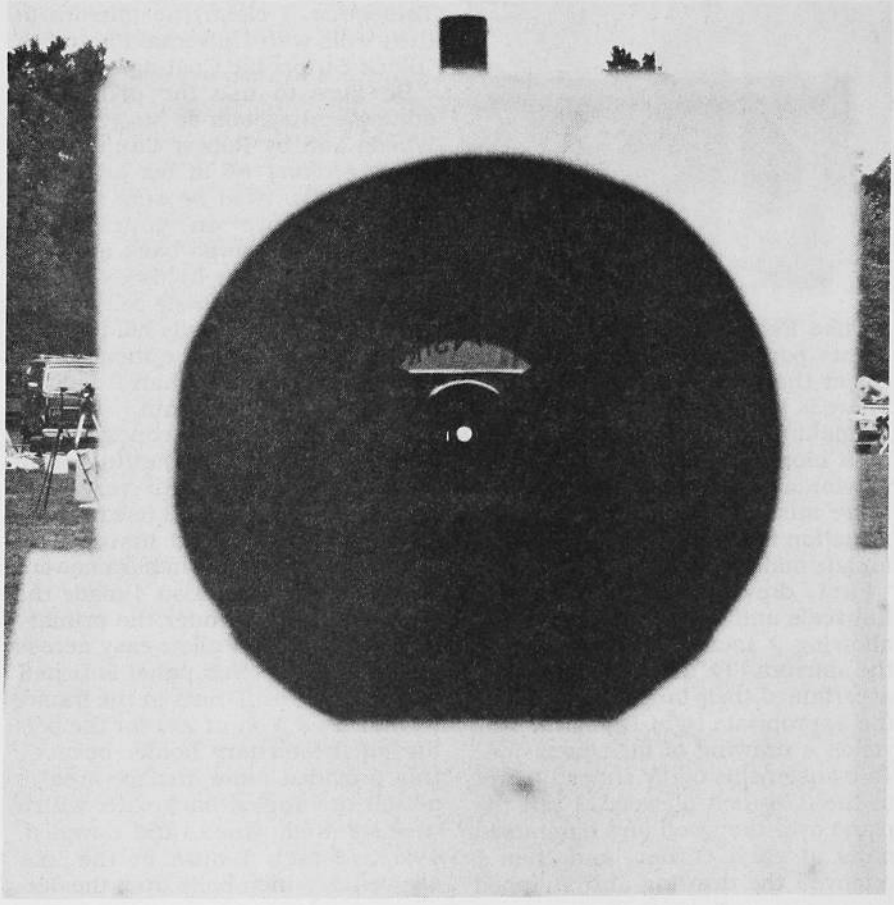
I recommend using 1/4-inch plywood; this would save 15-20 pounds yet still retain proper stiffness. Three-eighths-inch plywood with a 1-inch by 1-inch or 1-1/4-inch by 1-1/4-inch framework should probably be used for a 12.5 inch.

For mirror mounts, I followed A. L. Woods' lead in *Telescope Making #16* except I used only plywood and silicon glue as suggested by Richard Berry in his book, *Build Your Own Telescope*. I clean the mirrors in their cells with Universal Photonics' "Black Strippable Coating."

Be sure to use the orthogonal adjustment system as suggested by Woods and by Robert Cox in *Telescope Making #6* in his article on mirror cells. *Also be sure* to have locking screws on your mirror mounts. I had to go back and add them. Collimation holds extremely well with properly made cells. There are no flimsy side walls holding any of the mirrors so the optical alignment is more stable than it is for a Newtonian or Cassegrain.

The primary and secondary mirror cells unblot from the tubes and can be reattached with very little change in collimation. I used T-nuts and threaded inserts installed in the 3/4-inch by 3/4-inch framework to attach the cells. Also, I made the short side panel under the primary side removable to allow easy access to the tertiary. This panel is bolted to the tube with T-nuts in the framework. I used a short 2x4 for the bottom of the tertiary holder because this provided more surface area to attach the angled backplate, which was screwed, glued, and doweled. Two 3/8-inch T-nuts in the 2x4 allowed 3/8-inch bolts from the out-





It takes a massive mount and fork to support the tube box of a large "schief" well enough to take advantage of the fine images that large unobstructed optics can produce, and a drive is essential. Left: View down the optical axis shows an images of the eyepiece and the secondary in the primary. The tertiary's reflection is too dark to see.

side of the tube to hold it in place once it was adjusted in the slot of the bottom of the tube.

I stiffened the tube where the declination trunions attach. For this, I used 1/2-inch plywood brace 12 inches wide and fitted the whole width of the side of the tube. To get the 2-inch focuser high enough off the tube, I glued two pieces of 2x6 together and drilled a 2.5-inch hole through them. The focuser was made per Woods' excellent article.

Balancing was simple. I used a golf ball and rolled the tube around on it until it balanced, as Wessling suggested. It was so close yo being perfectly balanced that almost no adjustment had to be made when the tube was installed between the fork arms of the mount.

References on Making Schiefspieglers

Telescope Making Articles

Oscar R. Knab, "Making a 3-Inch Schiefspiegler," *TM#1*, p. 4.

Robert A. Schmidt, "Constructing a 10-inch Kutter Schiefspiegler," *TM#4*, p. 8.

Robert A. Schmidt, "Adjusting a 10-inch Schiefspiegler," *TM#7*, p. 32.

A. L. Woods, "Building a Kutter 3-Mirror Tri-Schiefspiegler," *TM#16*, p. 10.

A. L. Woods, "Collimation for a Kutter Tri-Schiefspiegler," *TM*#16, p. 18.

Richard J. Wessling, "Building a 12.5" Buchroeder Tri-Schiefspiegler," *TM#28*, p. 32.

Steve W. Johnston, "Construction of a Second 12.5-inch Tri-Schief-spiegler," *TM#28*, p. 44.

Books

Alan Mackintosh, ed., *Advanced Telescope Making Techniques*, 2 vols., Willmann Bell, Richmond, VA, 1986. Volume one contains valuable information on TCTs.

Harrie Rutten and Martin Van Venrooij, *Telescope Optics: Evaluation and Design*, Willmann Bell, Richmond, VA, 1988. This is especially valuable in describing TCTs and also deals with the problem of aperture obstruction.

Articles in *Sky & Telescope*

F. Salomon, "The Neo-Bracht Reflector," 8/58, p. 529.

O. R. Knab, 8/58, p. 553.

C. B. Avera, "An Oblique Reflector as a First Telescope," 5/61, p. 293.

O. R. Knab, "An Improved 4.5-inch Unobstructed Oblique Reflector," 10/61, p. 232.

O. R. Knab, "A Wall-Mounted Schiefspiegler for Lunar and Planetary Work," 5/63, p. 292.

R. A. Buchroeder, "CHT: A Catadioptric Herschelion Telescope with Tilted Components," 1/71, p. 46.

R. A. Buchroeder, "A New Three-Mirror Off-Axis Amateur Telescope," 12/69, p. 418.

R. E. Cox, "Telescopes with Unobstructed Light Paths," 2/72, p. 117.

A. Kutter, "A New Three-Mirror Unobstructed Reflector," 1/75, p. 46.

A. Kutter, "More about the Tri-schiefspiegler," 2/75, p. 115.

Collimation

This was much easier than I had anticipated. I followed Woods' procedures closely, and collimation went very quickly. The collimation is different from a Newtonian, but one should not confuse the "differentness" with inherent difficulty. The first time I tried to collimate a Newtonian took a while, but it was much easier after that. The same holds true for a trischiefspiegler. Three mirrors are about 1.5 times as difficult as a Newtonian.

First use an alignment target as Woods suggests, and then follow his directions on star alignment. The key is to get the axis of the astigmatism aligned with the optical axis and then adjust it until the star image is round. This can be done by adjusting the primary mirror, which is close to the eyepiece, so one can adjust while one watches through the eyepiece -- a much easier proposition than with the typical Newtonian.

Equatorial Mount

I already had a heavy duty fork mount for my 17.5-inch Newtonian. All I did was make a new fork out of 1/2-inch plywood over an inner framework of 2x2s glued and screwed together. The inside and the bottom of the fork were of 3/4-inch plywood with extra 2x2 support in the sides to insure that it didn't crush when it was bolted with 1/2-inch threaded rod to the polar disk. The fork is 12 inches deep and the arms are 8 inches wide. This produces an extremely rigid fork that dampens vibrations exceedingly well. The declination bearings are made of UHMW plastic as suggested by Tom Clark and Vic Meinard in "Gleanings for ATMs" in the March 1987 *S&T*. The bearings work extremely well.

The equatorial base is quite heavy. It is constructed of 4-inch by 4-inch, 2-inch by 4-inch, and 2-inch by 2-inch steel tubing. The polar shaft is a 2.5-inch solid steel shaft. The south bearing is a pillowblock and the north bearing is a 15-inch by 3/4-inch aluminum disk attached to the shaft with a 7-inch by 3-inch steel flange.

The disk rolls on two 1-inch roller bearings. This produces a terrifically strong mount and should be used more often. The drive is a 10-inch Mathis drive with a Hurst Model T synchronous motor. The whole mount, though simple, is quite solid, and vibrations dampen in a couple of seconds at most. One can focus at 1,000x and not lose the image.

The performance has been quite gratifying. Planetary viewing is excellent and so is deep-sky observing. With an 80mm Plossl I can get a 4mm exit pupil at 63x, which makes the f/20 trischiefspiegler suitable for deep-sky viewing -- in fact because it is a well-baffled design it offers excellent contrast for faint deep-sky objects. The dark sky background is beautiful, not to mention its value in discerning faint details.

Aperture for aperture, I don't think the trischiefspiegler can be beat. It is unobstructed and color-free. It is common knowledge that the obstruction of a typical reflector degrades the image, no matter how excellent the optics. This becomes extremely apparent when one uses an unobstructed system. The extra effort in making a trischiefspiegler is well spent. Don't let its differentness deter you from having a dream telescope.

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The Rutten Newtonian: A High-Performance Planetary Telescope

We wish to report a compact telescope with a spherical f/4 primary mirror and a color-corrected three-element lens that increases the focal length to f/15. This optical system is diffraction limited and has an aperture obstruction of less than 20 percent, which makes it ideal for planetary and lunar observing. Figure 1 shows the layout of the spherical mirror with the corrector, and figure 2 shows the corrector itself.

The advantage of long-focus systems is that high powers can be obtained without resorting to eyepieces that have short focal lengths and low eye reliefs. When such a system is used for photography, a large image scale is achieved. Moreover, eyepieces will give very sharp images when used with slow telescopes.

Planetary observers typically prefer a focal ratio of f/15. This is no problem for refractors or Cassegrain designs, and it can be readily achieved by using 3x Barlow lens with a f/5 Newtonian.

However, few mirror systems have a central obstruction smaller than 25 to 30 percent of the aperture. When low-contrast planetary and lunar details are studied, this obstruction should be as small as possible. Although an unobstructed telescope would be preferable, a 250mm f/15 refractor is a rather awkward instrument. Schiefspieglers of this aperture are also very big and may be difficult to adjust.

Classical Alternatives

It is very difficult to reduce the secondary diameter of a Cassegrain below 25 percent of the aperture. If we desire a value of maximum 20 percent (including the baffle tube system), then we must resort to a Cassegrain with a very high secondary magnification factor. For such an instrument the diameter of the strongly curved secondary mirror, without the baffling system, would be approximately 15 percent, resulting in this particular design with a secondary magnification factor of nine times and an f/1.7 primary mirror. These mirrors must be deformed to hyperboloidal and paraboloidal surfaces, respectively. Because of the very strong curvatures, this system would be far from easy to construct; moreover, the focal surface of such an instrument would be very strongly curved (see **Telescope Optics: Evaluation and Design**, page 63). Only on this curved field can a good sharpness be obtained.

Figure 3 shows the spot diagrams for a classical Cassegrain. The upper row spot diagrams show the images of a star at a flat focal surface; the lower row spot diagrams are those on the optimally curved focal surface. Note that it has a radius of only 70 millimeters!

An additional disadvantage of a low-obstruction Cassegrain designs is vignetting and flooding of the focal surface. Because of the very small obstruction, it is only possible to make a small, shielded field. This means that the whole of a 35mm SLR frame cannot be illuminated without a substantial loss of light in the corners of the frame when the obstruction is less than 20 percent. After weighing all these arguments, we conclude that a Cassegrain telescope is not an optimal design for this purpose.

Design Criteria for the Rutten

Inspired by the article of Robert Schalck of a catadioptric 300mm f/6 design (see *Telescope Making #31*, page 20), we asked ourselves whether it would be possible to design an f/15 planetary telescope based on Schalck's idea. Because of the small field angles for planetary and lunar observations, the field covered could remain small.

The lens combination we hoped to design would simultaneously accomplish the following functions:

- Multiply the mirror's focal length.
- Minimize the central obstruction.
- Correct the mirror's spherical aberration.
- Correct the mirror's coma and astigmatism.
- Flatten the field.

We established the following design parameters:

Aperture:	250mm
Speed:	f/15
Color correction:	Better than an achromat
Obstruction:	20 percent max
Use:	Primarily visual, but photographic use desirable
Surfaces:	All spherical
Optical components:	Minimum number
Glass:	Inexpensive types
Image surface:	Flat
Useful field:	0.25 degrees minimum (16.5mm), but if possible 0.50 degrees (32.7mm)

A catadioptric scheme similar to the Schalck Newtonian, having only spherical surfaces and an f/4 primary mirror, was developed in 1979 by Bird and Bowen, but it had a secondary magnification of 1.5 times. (See "A Compact All Spherical Catadioptric Newtonian Telescope," *Telescope Making #3*, Spring 1979, page 14, and **Telescope Optics**, page 130.) However, because they used only two lenses, the designers could not correct curvature of field and astigmatism.

The small central obstruction could be achieved only by placing the corrector between the primary mirror and the diagonal. This is because the negative lens combination not only increases the back focal length of the telescope but also intercepts the converging light

Figure 1:
Optical Layout
of the 250mm f/15
Rutten Telescope

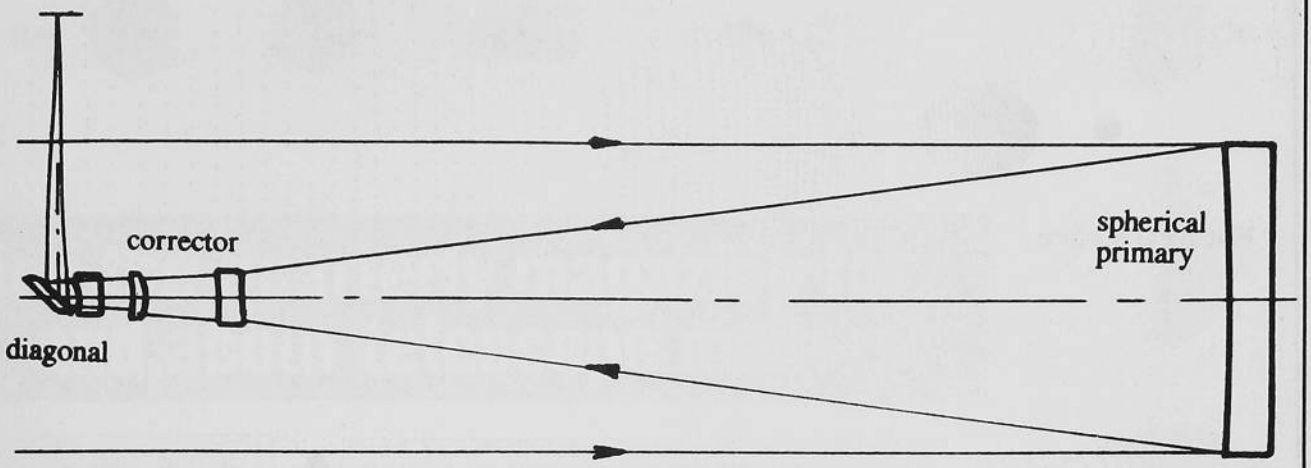
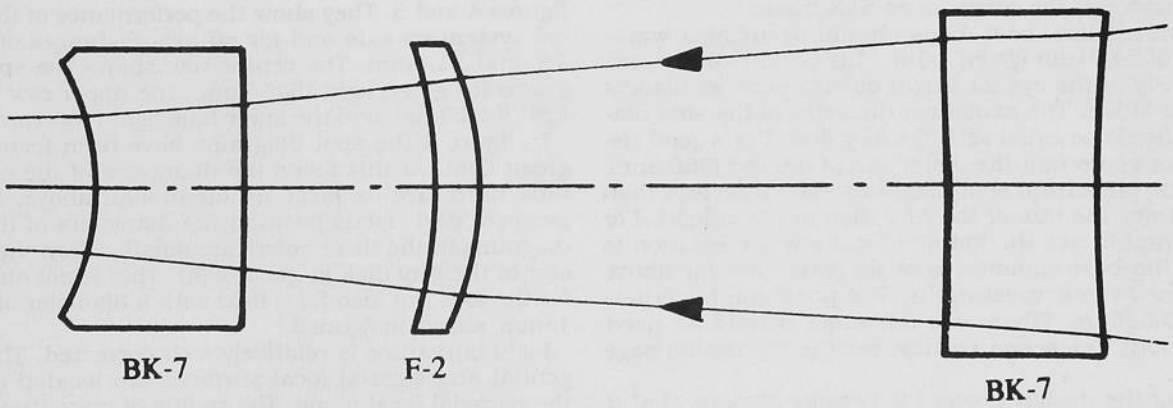
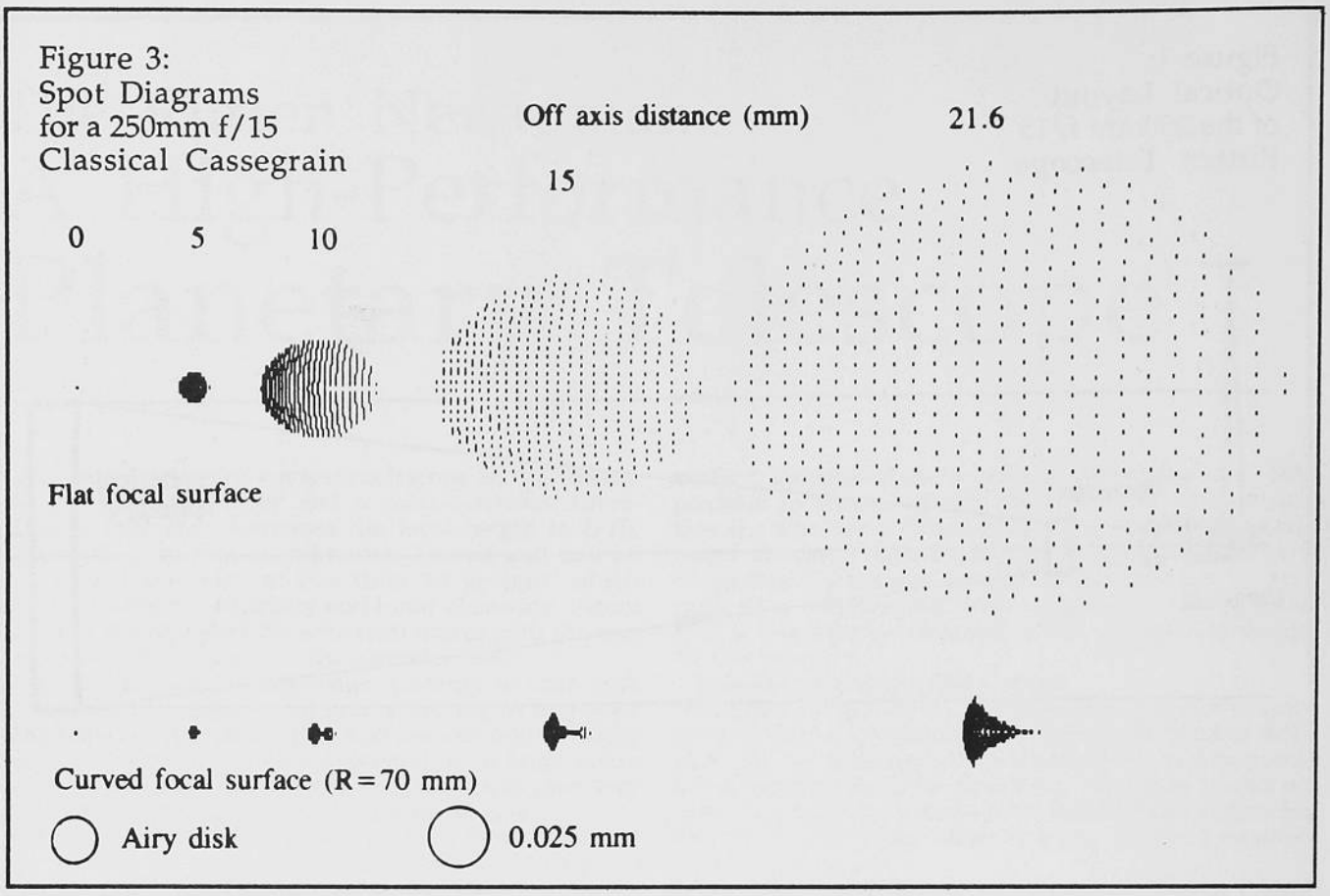


Figure 2:
The Rutten-Newtonian
Corrector Lens





cone closer to the focus of the mirror, where the cone is relatively small.

To meet the visual and photographic criteria, we carried out analyses for different positions of the focal surface, at 5, 10, and 15mm from the optical axis. We selected these distances as the edges of high-power, moderate-, and low-power eyepieces. The off-axis distance of 15mm is a very reasonable value for lunar photography too. For the sake of completeness we also analyzed an off-axis distance of 21.6mm to show the performance at the corner of an SLR frame.

For visual use, best focus should occur at a wavelength of 546.1nm (green light). This is close to the peak sensitivity of the eye for bright objects such as planets and the Moon. The maximum diameter of the spot diagram should be equal with the Airy disk. For a good visual color correction the diameters of the red (656.3nm) and blue (480.1nm) spot diagrams should be less than three times the size of the Airy disk in green light. For photographic use the optimal focal surface position is where the best common spot diagrams are for above mentioned three wavelengths. The photographic criterion is 0.025nm. (These are the same criteria we used throughout **Telescope Optics**; see the discussion page 55.)

During the design process it became obvious that it was not possible to comply with the demands given above when only two lenses are used. Therefore, our design incorporates a three-lens corrector with a spherical f/4 mirror. The corrector consists of two BK-7 and one F-2 lens and gives a secondary magnification factor of 3.75. The accompanying table shows the optical data.

Evaluation of the Rutten

The design has an excellent image at 546.1nm on the axis. The deviation at the wavefront is only 1/32 wave. The color aberration could not be fully corrected, but it is low and the sizes of the red and blue blurs are comparable with an f/15 semi-apochromatic refractor objective. The red-light blur is about 1.8 times the diameter of the Airy disk in green light; for blue light it is about 1.6 times.

The spot diagrams for the telescope are shown in the figures 4 and 5. They show the performance of the optical system on-axis and for off-axis distances of 5, 10, 15, and 21.6mm. The center row shows the spot diagrams for green light (546.1nm), the upper row for red light (656.3nm), and the lower blue light (480.1nm).

In figure 4 the spot diagrams have been focused for green light. At this focus the diameters of the red and blue blurs are as large as mentioned above. For an average "best" focus position the diameters of the spot diagrams in the three colors are smaller than the diameter of the Airy disk in green light. This is not only true for the axis but also for a field with a diameter of about 15mm, shown in figure 5.

Field curvature is relatively well corrected. The tangential and sagittal focal surfaces are located around the paraxial focal plane. The radius of curvature of the focal surface is about 650mm and is somewhat greater than a typical achromat of the same focal length. The photographic field is pretty good for a field with a diameter of 0.5 degree. Figure 6 shows the position of the tangential and sagittal focal surfaces.

Unlike baffled Cassegrain designs, the illumination of the field is very good. At the corner of an SLR frame the

Figure 4:
The Rutten Telescope
focused for green light

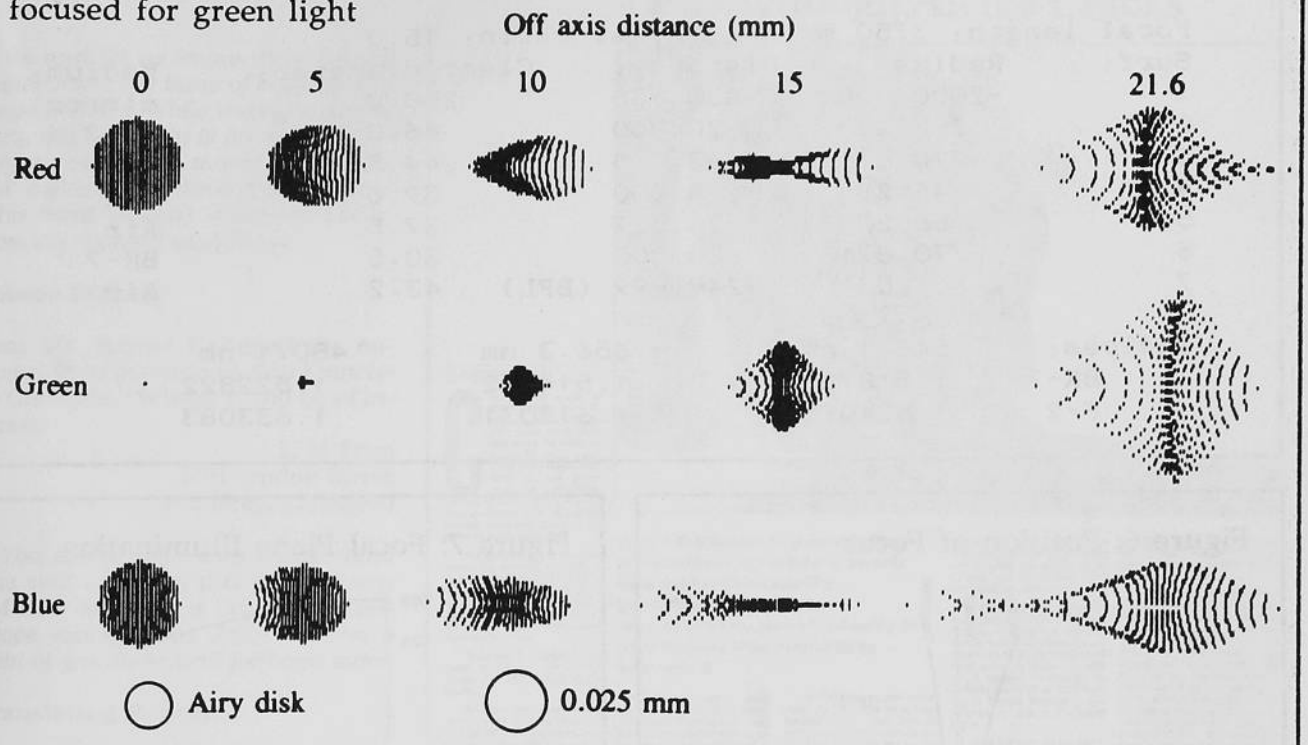
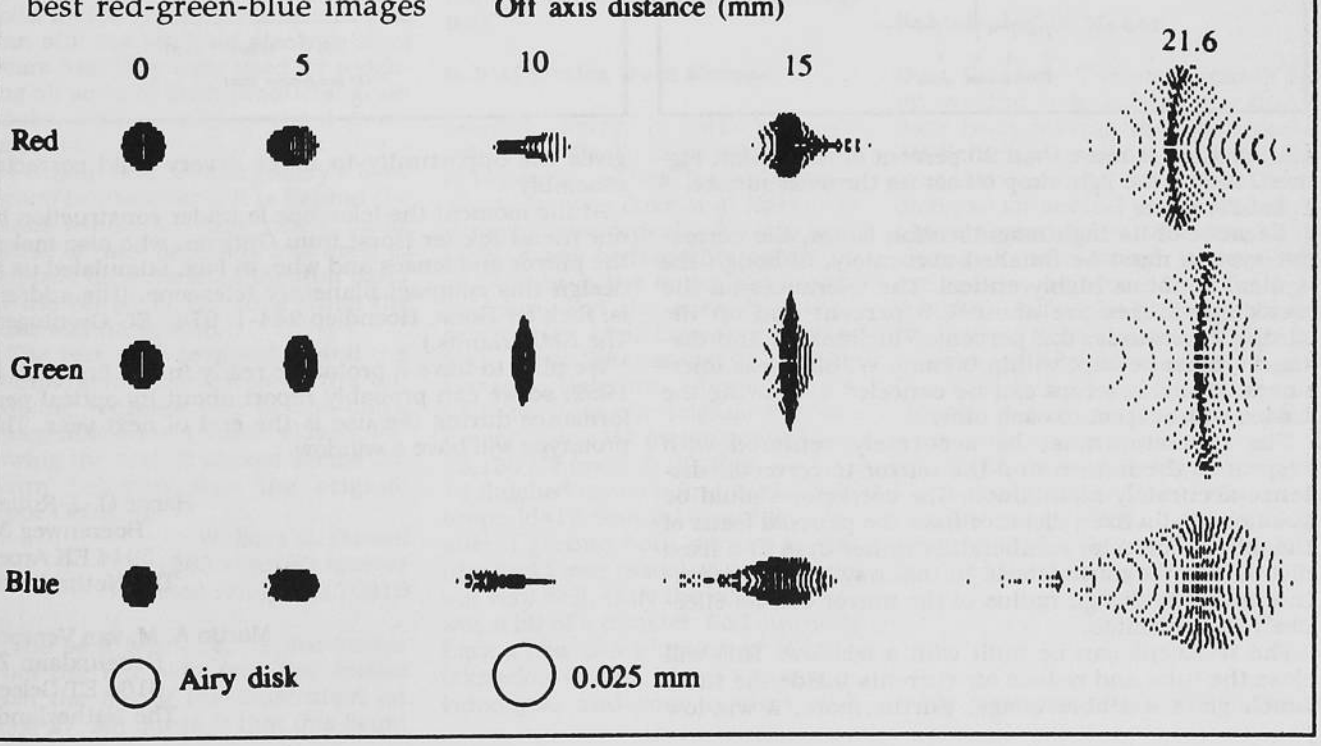


Figure 5:
The Rutten Telescope
focused for
best red-green-blue images



Optical Specifications for the Rutten Telescope

Focal length: 3750 mm, Focal ratio: 15.0

Surf:	Radius:	Distance:	Clear diameter:	Medium:
1	-2000.000	-830.338	250.0	mirror
2	293.003	-20.000	46.0	BK-7
3	-770.871	-63.065	44.5	Air
4	-45.285	-5.000	39.0	F-2
5	-68.205	-26.527	37.5	Air
6	-770.871	-20.000	30.5	BK-7
7	-34.039	-249.999 (BFL)	43.2	Air

Indices:	546.1 nm	656.3 nm	480.1 nm
BK-7	1.518720	1.514322	1.522822
F-2	1.624078	1.615031	1.633083

Figure 6: Position of Focus

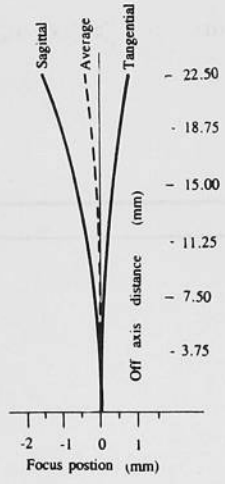
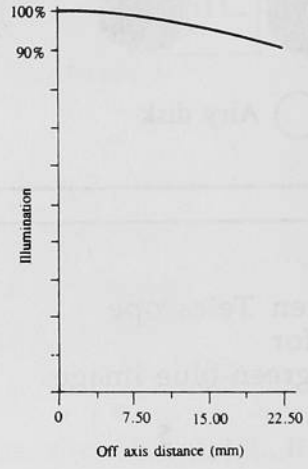


Figure 7: Focal Plane Illumination



illumination is more than 90 percent of the center. Figure 7 shows the light drop off across the focal surface.

Fabrication

Because of its high magnification factor, the corrector system must be finished accurately, although the system is not as highly critical. The tolerances on the weak curvatures are about 0.5 percent and on the strong curvatures, 0.2 percent. Thicknesses and distances must be kept within 0.1mm. Within these tolerances, residual errors can be canceled by moving the lenses with respect to each other.

The corrector must be accurately centered with respect to the mirror, and the mirror-to-corrector distance accurately maintained. The corrector should be positioned at a fixed distance from the paraxial focus of the mirror-corrector combination rather than at a fixed distance to the mirror itself. In this way a small departure from the design radius of the mirror can be effectively compensated.

The telescope can be built with a window. This will close the tube and reduce air currents inside the tube, which gives a stable image. Furthermore, a window gives the opportunity to make a very solid corrector assembly.

At the moment the telescope is under construction by our friend Rik ter Horst from Opticon, who also makes the mirror and lenses and who, in fact, stimulated us to design this compact planetary telescope. (His address is: Rick ter Horst, Hoendiep 244-1, 9745 EG Groningen, The Netherlands.)

We plan to have a prototype ready in the first half of 1989, so we can probably report about its optical performance during the use is the end of next year. The prototype will have a window.

Harrie G. J. Rutten
Boerenweg 32
5944 EK Arcen
The Netherlands

Martin A. M. van Venrooij
Beneluxlaan 74
6164 ET Geleen
The Netherlands

Letters

write and let us know. Poor optical systems are the bane of modern telescope makers. While testing is necessary, the necessity is an insult to the buyer pays good money for glass. TM welcomes letters from readers who have bought excellent optics from commercial suppliers.

Dobson in Need

Dear Mr. Berry/ I clipped the enclosed from yesterday's *San Francisco Chronicle*. Perhaps it will be of interest.

L. H. Price
675 Lyndon Street
Monterey, CA 93940

– You are not the only reader who has sent a copy of this story. Every TM who has built a Dobsonian telescope surely owes John Dobson a debt of gratitude, and perhaps more.

Translating Schröter

Dear Richard/ I thoroughly enjoyed reading your article on Johann Schröter's 27-foot Newtonian telescope at Lilienthal. "Steelyard" is probably an equally correct translation for Schnellwage. In rural America today, especially in older and smaller grain exchanges, haylofts, and in rural-life museums, you can still see working steelyards. In years past they were used for weighing all sorts of farm products: grain sacks, cotton bales, animal products, etc.

I cannot find "e" (the gallery's bent beam) but wonder if it is behind the main winch "c." Nor can I make sense of "nu" unless it was used to support the tube from the iron band at the center of the tube when the tube was horizontal.

The very poor perspective and the comparative crudeness of the engraving requires one to use one's imagination even when closely following the text. It almost seems Johann Schröter was the original Rube Goldberg.

Wallace G. Pursell
12635 Parnell Avenue
Baton Rouge, LA 70815

-- The bent beam, "e," is five inches from the left side and five inches from the top of the illustration on page 27. My guess is that this beam was sprung hard against the centerpost to prevent the pivot point from wandering. Your suggestion about the function of "nu" makes sense, especially considering the location of the iron band "phi" and its description.

SEASON OF SHARING

'I Fell Through All the Cracks'

BY MARK MacNAMARA

Consider the plight of John Dobson. He's 73, slight, approximately 5'8", with chalk-white hair and a list when he walks. He looks something like Douglas Fairbanks Jr., and underneath his considerable charm and eccentricity, you might imagine Dobson to be an English country gentleman down to his last acre of inherited land.

But Dobson's life is quite different. His situation is terrifying because it's so familiar. You know him. He's the relative who chose an admirable if difficult life, has never complained and has always been a mentor to others in trouble. Now he's in trouble.

As he puts it, "Nobody is supposed to fall through all the cracks, OK? I fell through all the cracks."

He never paid into Social Security, so has no money coming in each month. These days he teaches a class and earns $15 an hour for 16 hours of lectures — $240 in a year.

John Dobson is proof that education and hard work are not necessarily fortification against destitution, particularly if one takes the road less traveled

John himself went to Lowell, then the University of California at Berkeley, where he had a long love-hate relationship with education, but eventually graduated at age 28 with a degree in chemistry.

In 1967, Dobson was thrown out of the monastery for an unauthorized absence. He'd been off with his telescopes, teaching people about astronomy and the universe.

roughly 100 people who devote their time to building telescopes and offering the public, at no charge, basic information about the science of astronomy.

Dobson himself has spent the last 20 years working with his organization, traveling and lecturing. He has written two books on religion and science. He has lived off small honoraria. Right now, Dobson is teaching "Astronomy for Children Under 60" at the Josephine D. Randall Museum in San Francisco at 7 p.m. on Wednesday nights.

Until last year, he worked as an apartment manager. It was an pays $225 a month for a small room and kitchen privileges. It's an arrangement he wants to keep, but can no longer afford.

Dobson is proof that education and hard work are not necessarily fortification against destitution, particularly if one takes the road less traveled. But he is a model of how to grow old and retain energy, purpose and dignity. He walks up Mt. Tamalpais several times a month. He is always on the move, driving around the city in his beat-up van full of telescopes, forever standing before classes of schoolchildren demonstrating some wondrous thing about the cosmos.

Schief Optics from Europe

Dear Mr. Berry/ In *TM#4* you published Mr. Field's letter asking about ready-made optics for Schiefspiegler telescopes (known in Europe as Kutter telescopes). A company making very high-quality optics, including both the optics for Schiefspieglers and the assembled telescopes is: Lichteknecker Optics N.U., Grote Breemstraat 21, B-3500 Hasselt, Belgium. Phone (0) 11-253026. Prices in Belgium vary between 23,450 Bfr (roughly $780) and 65,130 Bfr (roughly $2,200)

I finished my own first Kutter telescope (d=12.5cm f=162cm) last August. I ground both mirrors myself (the first I ever made) and they came out very well. Only the silver coating was a bit of a disaster. So I currently have a new pair aluminized at Lichteknecker Optics. I hope I have provided you and your readers with useful information.

Mark Bosselaers
L.V. Berckehlann 90
B-2600 Berchem
Belgium

Schiefspiegler Maker

Dear Richard/ The main reason for my writing is to inform you that I have been making the Buchroeder Tri-Schiefspiegler optics for amateur astronomers, and have been doing so for several years. Although I have chosen not to advertise, I still manage to have enough jobs to keep me as busy as I have time for. But you *did* ask if anybody else out there made these in the last issue of *TM*...

It was good to see the fine images Dan's Schiefspiegler 10-inch provided at Astrofest. I, too, have been geting superb images on the excellent nights of good seeing. One night I was doing better than 1/2-arcsec resolution on Mars. I was almost overwhelmed trying to draw it all— but I did the drawing anyway.

Richard J. Wessling
5429 Overlook Drive
Milford, OH 45150

– My apologies, Dick, but I didn't

Letters

know you produced schief optics for sale! It's my guess that Schiefspieglers will remain a specialty telescope for amateurs with above-average gumption to build. I'm glad to see several sources of these optics are available for mechanically skilled optical rookies, even though the finished telescopes are huge—as you yourself know!

Jones-Bird Lenses Wanted

Dear Mr. Berry/ I am wondering if one of the small lens makers out there would be interested in making the negative doublet for a Jones-Bird telescope. The specs are in *TM#3*, page 15, for a 12.5-inch primary. Anyone interested in fabricating these two lenses for me please send a price quotation.

Kurt King
1702 Valley View Drive
Austin, TX 78733.

-- Depending on your observing program, you might want to wait and consider building the new Rutten telescope instead. If there is significant interest in this design, you and others might be able to obtain a "group buy" price on the lenses and housings for them.

The Gizmo Works!

Dear Richard/ At the recent Astrofest I displayed my new 17.5-inch Dobsonian built with birch plywood and veneer. This instrument also featured the new Lumicon Sky Vector electronic setting circles. I had just installed them the day before Astrofest and did not have time to get the bugs out. As a result, they did not function properly and people were left with idea that there was something wrong with Lumicon's product. I'm writing this letter with the hopes of dispelling that perception.

I called Jack Marling the day after Astrofest and we determined that the problem was in the installation diagram. It showed the altitude encoder on the wrong side of the telescope. Jack instructed me to reverse two wires on the wiring harness and all would be well. The other solution was to remount the encoder on the other bearing, which was not practical for me from an aesthetic viewpoint.

After I switched the wires the gizmo worked like a charm. I'm actually somewhat embarrassed at the ease in which I can locate objects. I'm using my telescope more often and finding things I never would have looked for before. I can open up my *Burnham's* to a constellation and "browse" the deep-sky objects in the area.

Once again Lumicon, and in particular Dr. Marling, has shown that they care about us little guys and can be depended upon for support. I hope other manufacturers and dealers will take note and follow suit.

Donel D. Wyman
1815 Kienast Avenue
Oshkosh, WI 54901

—The trigonometry embedded in those marvelous devices could help every telescope maker. Here's one for the math wizards: given three matching altitude-azimuth and RA and Dec coordinate piars, how do I solve for the latitude and hour angle? Being non-mathematical, I want this wisdom encapsulated in a nice BASIC algorithm. Any takers?

—
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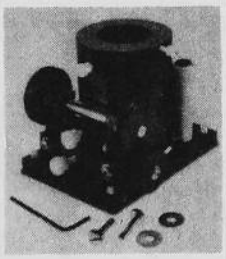

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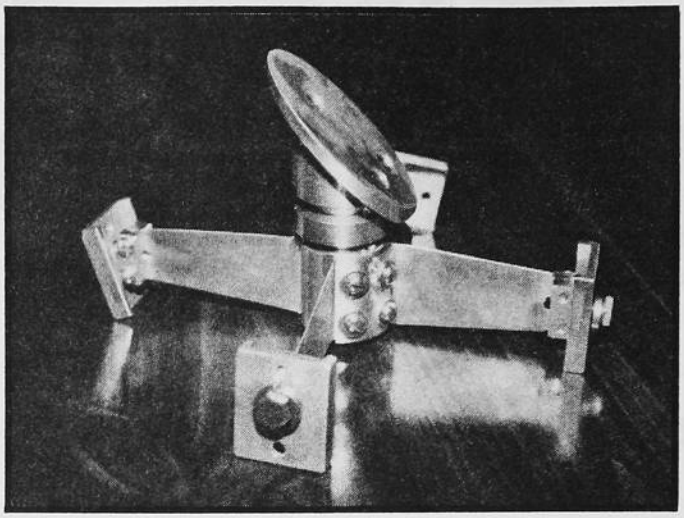

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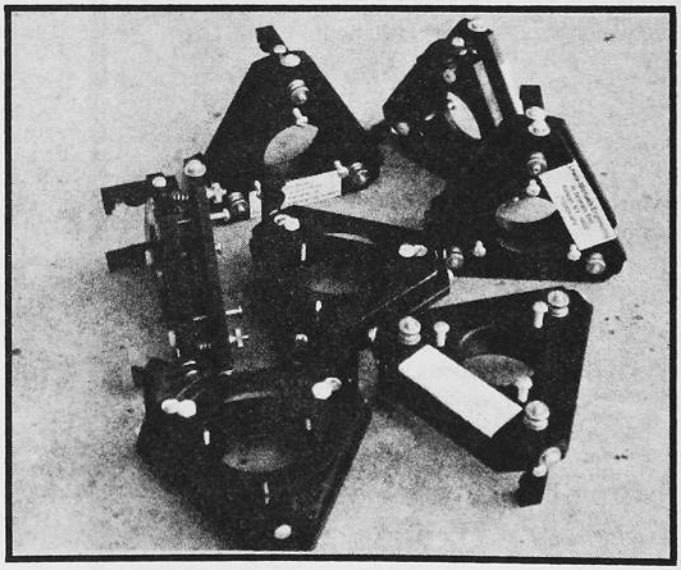

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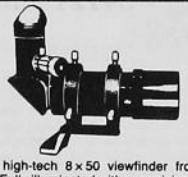

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Our binocular viewer is still the quality leader! Fits any 1¼" telescope. Uses two of your 1¼" eyepieces. Removable Barlow. 45° viewing angle **$475.00**

11×80 Amici

It's a fantastic viewfinder! It's a versatile rich-field telescope! It's a compact spotting scope for nature study! We started with an 80 mm fully coated achromatic objective. We added a **fine quality 1¼" rack and pinion, 30 mm 1¼" crosshair eyepiece, and a 1¼" Amici diagonal prism for correctly oriented images!** Complete with tripod mounting block. Beautiful midnight black finish. Perfect for comet hunting.

..... **$279.95**
With normal diagonal **$225.00**
KIT of all parts without diagonal or eyepiece $175
..... **$175.00**

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Merchandise Total	Shipping Charge
Up to $69.99	**$2.95**
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MARK-5 Visual — An extremely high contrast filter for visual use only. For areas of extreme light pollution. Gives remarkable results on planetary and emission nebulae. Very narrow bandpass. For all 1¼" eyepieces. Premium grade **$75.95**

MARK-5 Photo Visual — This is the choice for photo and visual use on most deep-sky objects. The broad band makes it ideal for astrophotography. For all 1¼" eyepieces. Premium grade **$75.95**

Variable Density Polarizer — For 1¼" eyepieces. Reduces the glare on bright objects. Our unit has two glass filters in a rotating cell. (range is about 5% to 30% blockage) **$32.95**

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A Major Advancement in Illuminated Eyepieces!

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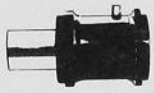
Camera Adapter



Professional Camera Adapter — Couples your camera to any 1¼" O.D. focuser. Excellent quality anodized aluminum. For first focus and eyepiece projection. Threaded for 27mm photographic filters. Standard T-thread. Use with camera T-ring listed below **$34.95**
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T- Camera Rings

Camera T-Rings — Pentax K, Pentax S, Yashica, Canon, Minolta, Exakta, Konica, Olympus OM-1, OM-2 ..... **$12.95**
T to C Mount — Attaches TV cameras with "C" mounts to standard T-adapters **$20.95**

New Items

3 Power Klee — This unusual Barlow has three elements, each element being air-spaced from the other elements in the system. 1¼" O.D. ... **$75.00**

9mm Plössl with Adjustable Reticle Positioning. Completely self-contained. Unique guiding reticle can be moved anywhere in field with micro-adjusters! 2 SR-44 batteries included **$129.95**

Wide Scan 80 degree Field! Now you can experience the thrill of extreme wide angle viewing without the size, weight, and expense usually associated with this type of eyepiece. Available in 10mm, 13mm, 20mm, and a 7-element 25mm with a 70 degree field. 1¼" O.D. **Price for 10mm and 13mm $130.00 ea. 20mm and 25mm** ..... **$150.00 ea.**

2" Prismatic Star Diagonal

No more mirror surfaces to scratch or recoat. Giant full-aperture glass prism. Remarkable!
Price **$179.00**

Deep-Sky Binoculars

These are the same excellent quality 80mm giant binoculars that we have sold for years. Available in 11 power or 20 power and come complete with tripod adapter, collimation certificate, and case. **New multi-coated models available.** Please call **Toll Free** for latest price.

Special Plössls

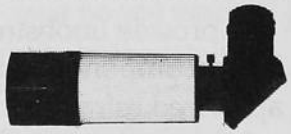
University has finally broken the price barrier on top quality Japanese Plössl eyepieces. Sure you can pay a lot more, but can you really tell the difference? True 4-element Plössl design with multi-coating.

1¼" in 7mm, 12mm, and 20mm. Each **$49.95**
Special 1¼" 2x Barlow **$47.95**

Pretoria™ Eyepiece

This is the eyepiece many of you have read about that corrects for coma in fast Newtonian mirrors. Our first offering is in 28mm fitting 2" and 1¼" mounts. Introductory price **$225.00**
16mm **$195.00**

8×50 Viewfinders



This all new University 8x50 viewfinder uses standard 1¼" eyepieces. The cell, tube, and eyepiece holder are metal for years of service. Don't confuse this unit with those made mostly of plastic! Comes with 1¼" star diagonal, and 1¼" wide-field Kellner with crosshair. Fully-coated achromatic 50mm objective lens. Mounting bracket is extra. Choice of black or white finish.

Fits Celestron 8, Meade 2080, Odyssey, and most reflectors **$99.95**
Sturdy Mounting Bracket (six adjustment screws) **$19.95**
Straight-Through Adapter. Converts the above to straight through viewing **$10.95**

2" Star Diagonal

At last, an economical way to convert your telescope to 2" O.D. eyepieces!

Use with our 55mm Plössl. By using a clever design that allows you to screw our diagonal onto your **Meade, Celestron,** or **Dynamax** T-adapter, we saved weight and cut machining costs drastically. Diagonal slips in any 2" focusing mount **$110.00**
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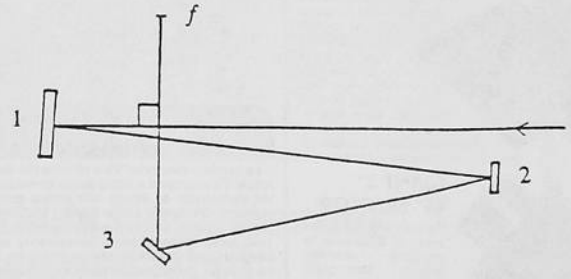
The 4.25" and 6.00" f/30 sets are the 2-mirror design by A. Kutter; the others are the 3-mirror design by R. Buchroeder.

Mirror set prices:

4.25" f/26	$299.00	8.00"	f/20 $1,185.00
6.00" f/30	$500.00	10.00"	f/20 $1,500.00
6.00" f/20	$745.00	12.50"	f/20 $2,200.00

Tube assembly prices:

4.25" f/26	$900.00	6.00"	f/30 $1,400.00



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Computer-Controlled Digital Setting Circles, from $498

Incredibly Smart! thus Incredibly Easy!

- Digital right ascension readout to 1 minute of R.A.
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- Polar alignment **not required!**
- Just sight two stars!
- Works for alt-azimuth **and** equatorial mounts

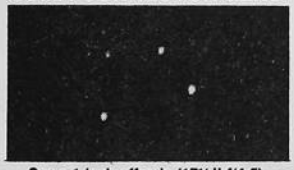
LUMICON Sky Vector™ (state scope) **$498**
Sky Vector™ Kit (you supply hardware) **$469**
Pair digital shaft encoders (for 2nd scope) **$135**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers perfer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat. The deluxe SUPER-FINDER uses an 80mm, F=500mm air spaced achromat.

1¼" 50mm Finderscope **$59.50**, right-angle **$89.50**
1¼" straight-thru 80mm SUPER-FINDER **$169**
1¼" right-angle version, w/star diagonal **$195**
2" right-angle version, non-rotating focuser **$199**
1¼" Deluxe right-angle Super-Finder **$279**
2" Deluxe right-angle Super-Finder **$309**
25mm Cross-hair 1¼" eyepiece (12X) **$29**
1¼" Star Diag. . . **$32**, 2" Star Diag., silver, . . **$145**
1¼" Amici Prism diag. for correct left-right views **$59.50**

COMA CORRECTOR LENS



Coma 1 inch off-axis (17½" f/4.5)

Same Field with LUMICON coma corrector lens; note smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. It threads into LUMICON 2" EASY-GUIDERS for effortless installation. This lens is optimized for f/4.5 and reduces aberrations for f/3.5 to f/5 Newtonians. Off-axis images are much smaller, making off-axis guiding far easier and yielding round pinpoint star images in photos. Since star images are sharp over a full 2¼" circle, you can use medium format cameras in addition to 35mm cameras. This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Although designed for photography you may also use this lens to improve image quality in wide-field viewing with low power eyepieces.

LUMICON Coma Corrector/Field Flattener
2" lens **$285.00**
Extension tube for viewing **$26**
2" Easy-Guider™ (state camera) . . **$169.50**

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For phone orders please call (415) 447-9570
LUMICON Products catalogue $2.
Foreign orders add $8 ($20 for HYPER-KITS)
California Residents add 6% tax.
Prices subject to change w/o notice.

NEW! ENCHANCED SILVER DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3" & 3.1" enhanced silver diagonal mirrors & 2" star diagonal.
The new LUMICON diagonal mirrors have a special enhanced silver coating with a protective overcoating for long life. Visible reflectivity is 98-99% compared to 86-89% for standard aluminum coated mirrors. The extra 10-12% transmission is like adding an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32" **$29.95** 1.52" **$34.50** 1.83" **$39.50**
2.14" **$49.50** 2.60" **$65.00** 3.10" **$89.50**
4.25" **$149.50**

ENHANCED SILVER STAR DIAGONAL

90° star diagonals with above enhanced silver mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.
1¼" (1.32" mirror) **$89.50**
2" (1.83" mirror)(see photo above) . . **$145.00**

OXYGEN-III FILTER

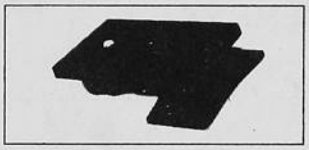
Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90% for both O-III lines at 496nm and 501nm.

Filter Type	1¼"	48mm
Lumicon Oxygen-III	**$99.50**	**$199.50**
Lumicon UHC	**$99.50**	**$199.50**
Lumicon Deep-Sky	**$79.50**	**$119.50**
Set UHC and Oxygen-III .	**$190.00**	**$380.00**

NOTE: The Oxygen-III Filter is not a substitute, but a compliment to the UHC Filter. **1 year guarantee:** You must see nebulae with the O-III filter that are **invisible** without a filter.

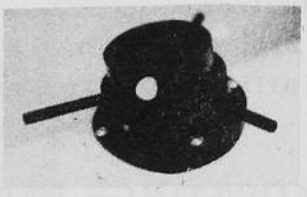
NEW ADJUSTABLE PIGGYBACK MOUNT



LUMICON has just designed a new adjustable piggyback mount ideal for all telescopes of 8-14" aperture. It has **both** vertical and sideways adjustment to allow optical alignment. It was designed to allow mounting of the LUMICON SUPER-FINDER on C-8, C-14, etc., but is ideal for any telephoto lenses or small telescopes.

Deluxe Piggyback Mount $45.00
(State Telescope Type)
LUMICON 12x80mm SUPER-FINDER . $170

NEW! LOW PROFILE HELICAL FOCUSERS



LUMICON® DELUXE NON-ROTATING HELICAL FOCUSER on a 6" telescope.
LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.
Select your desired base-plate shape!
Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD, SUPER-FINDER base plate.
LUMICON 1¼" Helical Focuser $49.50
LUMICON 2" Helical Focuser $59.50
LUMICON Non-rotating Helical Focuser $79.50
3 handles (see photo) for non-rotat. focuser **$12.95**
2"/1¼" adapter w/48mm filter threads . . **$20.00**
2" LUMICON EASY-GUIDER $169.50

PROTECTIVE DUST COVERS

Protective plugs (left), vinyl dust covers.
Protect your valuable telescope optics, eyepieces and accessories with these black vinyl covers. Add $1 shipping. Deduct 10%, 2 or more sets.

1¼" O.D. plug, seals focuser . . . . . **4/$2**

2" O.D. plug .	**2/$2**	3½" O.D. plug	**$1.50**
1¼", 1⅞"	**3/$2**	7½"	**$8**
1½"	**2/$2**	9½", 10.4"* . . .	**$12**
2"	**2/$2**	12½", 12⅞"* . .	**$15**
3½", 4½"	**$5**	16"*	**$20**
5½"	**$6**	19" (DS-16) . . .	**$27**

*Fits Odyssey

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FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15X film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

†U.S. Patent 4,473,636

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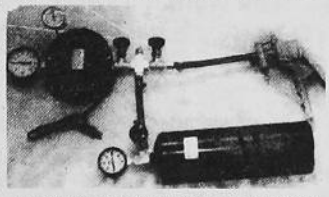
MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$295.00**



MODEL 600 HYPER-KIT (See Photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$350.00**

MODEL 1200 HYPER-KIT is for 4X5" plates and film up to 5X7". Has 2 gas cylinders and includes temperature controller **$595.00**

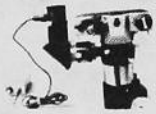
Temperature controller for any HYPER-KIT **$59.50**

Electric Vacuum Pump **$280.00**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms of bright guide-starts. *Specify Camera and Telescope type.*
U.S. Patent #4,448,500

NEWTONIAN EASY-GUIDER™



Full aperture. Installs in secs. Specify 2" or 1¼".

NEWTONIAN EASY-GUIDER **$169.50**
3X Relay Diagonal (see photo) **$79.50**
Illuminated reticle eyepiece system . . **$79.50**
Guider for Hasselblad **$350,** Mamiya 645 **$159**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Dynamax-8. Includes 50mm achromatic lens for f/5.8 operation —3X shorter exposures! **Superb rich field viewing, too!**
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GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) . . . . . **add $99.95**
Adapter for Hasselblad adapter **$195,** Mamiya 645, **$96**

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1. Illuminated reticle eyepiece **$79.50**
Lumicon 12mm eyepiece system has adjustable L.E.D. illumination, dual crosslines, battery pack.

2. Cable release for long exposures . . **$9.95**

3. **LUMICON Quartz Drive Corrector . $219**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 40Hz/80Hz variable output controls telescope drive. 60Hz Quartz reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Declination reverse switch for Newtonians.
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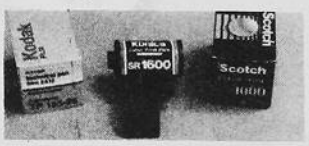
NEW Deluxe Digital Qtz. Drive Correc. **$298**



HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.).

Film Type, 35mm	Exposures	Price
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR3200, fastest of all, color neg	24	**$13.95**
Konica SR400, fine gr. color neg	12	**$10.95**
3M 1000, fastest slide film	20	**$12.95**
Fujichrome RD100, fine gr. slide	24	**$12.95**
5072, color slides from negs	36	**$6.95**
D-19 B&W Developer	1 gal.	**$6.95**

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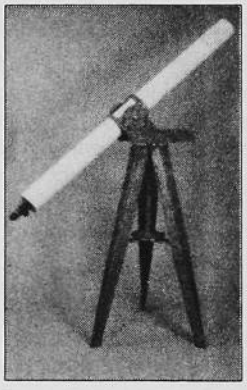

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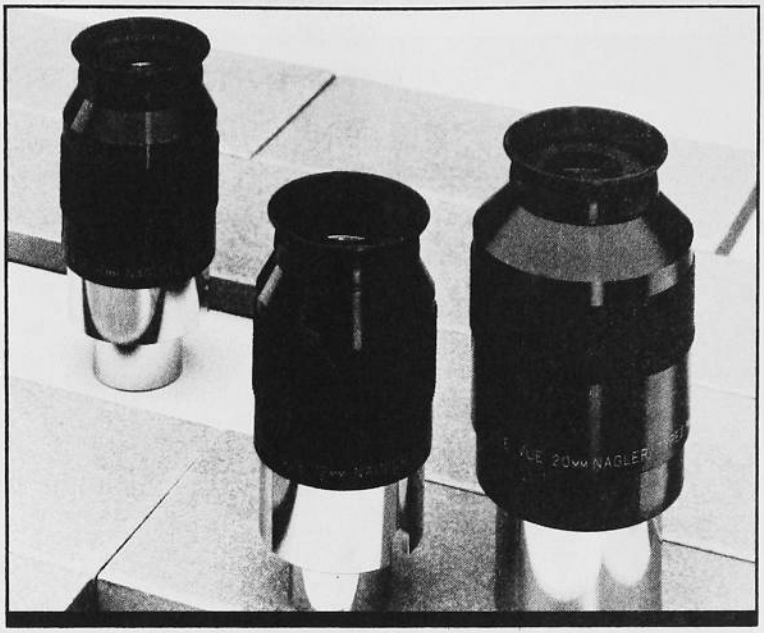
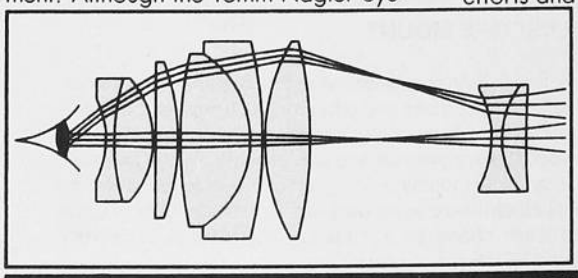


Design Goals

The basic Nagler series has already achieved image correction 10 times better than previous wide angle eyepieces (study in "Telescope Making" titled "The Nagler 13, a Remarkable Telescope Eyepiece"). We felt that extending the apparent field or image correction levels beyond that of the original Nagler series would *not* yield significant practical gains, but that extending the focal lengths *would* offer enormous potential for spectacular low power, wide-angle viewing.

In order to produce longer focal length Naglers, two practical limits had to be overcome:

1) Substantial physical size, weight, and cost increases would be impractical.
2) Scaling up exit-pupil aberrations would be unacceptable in our judgement. Although the 13mm Nagler eyepiece provides extremely sharp *images*, exit-pupil aberrations require a large (nighttime) eye pupil opening to encompass the full field. For this reason, daytime viewing with the 13mm Nagler is not recommended. Eye positioning is just too sensitive with the 7 element design to consider focal lengths longer than 13mm. The 9mm and shorter Naglers don't show this sensitivity.



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20mm Nagler Type 2

Has the largest true field in the series. Yet this eyepiece, (strictly for 2 inch focusers) is comparable in size and weight to a 13mm Nagler. There's nothing like this 20mm for viewing large open clusters, galaxies and nebulae. It gives a 4.5mm exit-pupil with f/4.5 telescopes. Daytime viewing is also simply stunning!

16mm Nagler Type 2

Offers far more true field than the 13mm Nagler, yet is smaller and lighter. Great day or night performance with any telescope.

"There is nothing like this eyepiece (20mm Nagler) for viewing large deep-sky open clusters, galaxies, and nebulae. Under ideal conditions at Yosemite National Park, I was treated to incredible views of M8, M13, M17, M22, M31, and M33. I had believed that my C-8 would never perform visually with photographic quality, but my observations with the Nagler rivaled the detail in good astrophotography and even surpassed it at times. I was amazed and deeply satisfied. Thank you for the ultimate eyepiece." Ben Cohen, CA

12mm Nagler Type 2

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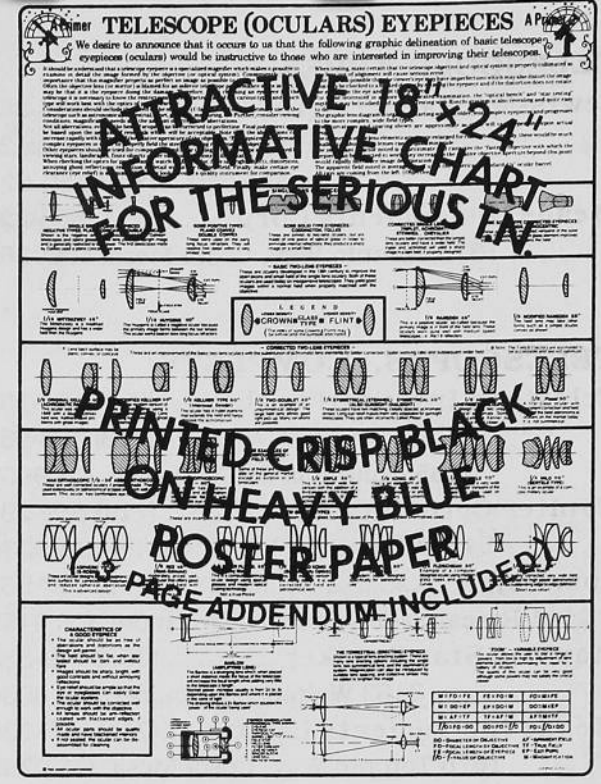

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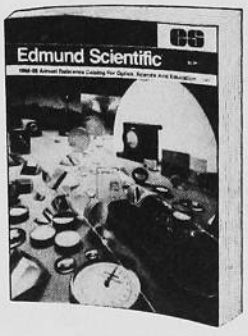

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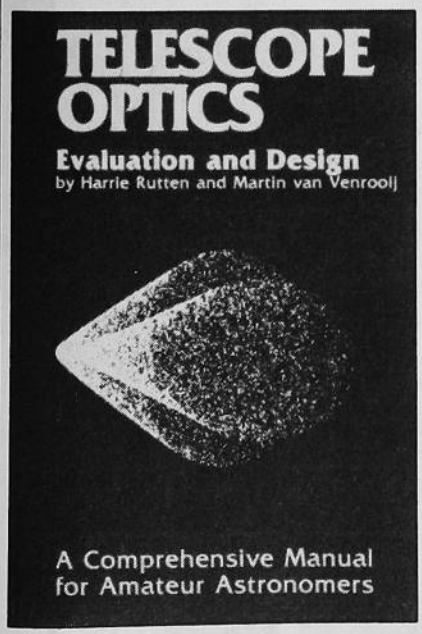

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